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MINERALS FOR THE CONSTRUCTION INDUSTRY

VOL. I

MINERAL MINING AND PROCESSING INDUSTRY

Point Source Category

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

OCTOBER 1975

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DEVELOPMENT DOCUMENT
for
INTERIM FINAL
EFFLUENT LIMITATIONS GUIDELINES
and STANDARDS OF PERFORMANCE

MINERAL MINING AND PROCESSING INDUSTRY

VOLUME I

Minerals for the Construction Industry

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ABSTRACT

This document presents the findings of an extensive study of selected minerals in the Minerals for the Construction Industry segment of the mineral mining industry for the prupose of developing effluent limitations guidelines for existing point sources and standards of performance and pretreatment standards for new sources, to implement Sections 301, 304, 306 and 307 of the Federal Water Pollution Control Act, as amended (33 U.S.C. 1551, 1314, and 1316, 86 Stat. 816 et. seq.) (the "Act").

Effluent limitations guidelines contained herein set forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available (BPCTCA) and the degree of effluent reduction attainable through the application of the best available technology economically achievable (BATEA) which must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. The standards of performance and pretreatment standards for new sources contained herein set forth the degree of effluent reduction available demonstrated control technology, processes, operating methods, or other alternatives.

Based on the application of best practicable technology currently available, 6 of the 9 production subcategories (comprising 15 minerals) under study can be operated with no discharge of process generated waste water pollutants to navigable waters. With the best available technology economically achievable, 8 of the 9 production subcategories can be operated with no discharge of process generated waste water pollutants to navigable waters. No discharge of process generated waste water pollutants to navigable waters is achievable as a new source performance standard for all production subcategories except mica, wet beneficiation process with ceramic grade clay as by-product.

Supporting data and rationale for development of the proposed effluent limitations guidelines and standards of performance are contained in this report.

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SECTION I

CONCLUSIONS

Total prevention of

For purposes of establishing effluent limitations guidelines and standards of performance, and for ease of presentation, the mineral mining industry has been divided into three segments to be published in three volumes: minerals for the construction industry; minerals for the chemical and fertilizer industries; and clay, ceramic, refractory and miscellaneous minerals. These divisions reflect the end uses of the minerals after mining and beneficiation. In this volume covering minerals for the construction industry, the 15 minerals were grouped into 9 production subcategories for reasons explained in Section IV.

of available

Based on the application of best practicable technology currently available, 6 of the 9 production subcategories under study can be operated with no discharge of process generated waste water pollutants to navigable waters. With the best available technology economically achievable, 8 of the 9 production subcategories can be operated with no discharge of process generated waste water pollutants to navigable waters. No discharge of process generated waste water pollutants to navigable waters is achievable as a new source performance standard for all production subcategories except mica (wet beneficiation process with ceramic grade clay as by-product). Mine water and contaiminated facility runoff discharge are considered separately for each subcategory.

This study included 15 minerals for the construction industry of Standard Industrial Classification (SIC) categories 1411, 1422, 1423, 1429, 1442, 1446, 1492, and 1499 with significant waste discharge potential as given in the following list with the corresponding SIC code.

1. Dimension Stone (1411)
2. Crushed Stone (1422, 1423, 1429)
3. Construction Sand and Gravel (1442)
4. Industrial Sand (1446)
5. Gypsum (1492)
6. Asphaltic Minerals (1499)
    a. Bituminous Limestone
    b. Oil Impregnated Diatomite
    c. Gilsonite
7. Asbestos and Wollastonite (1499)
8. Lightweight Aggregate Minerals (1499)
    a. Perlite

    - b. Pumice
    - c. Vermiculite

9. Mica and Sericite (1499)

SECTION II

RECOMMENDATIONS

The recommended effluent limitations guidelines and the suggested technologies are listed in Table 1. pH should be maintained between 6.0 and 9.0 units at all times.

The pretreatment standards will not limit total suspended solids or pH, unless there is a problem of sewer plugging, in which case 40 CFR 182.131(c) applies. Limitations for parameters other than TSS and pH are recommended to be the same as proposed for best practicable control technology currently available (for existing sources) and for new source performance standards (for new sources).

Table 1

Recommended Limits and Standards for the Mineral Mining and Processing Industry

The following apply to process waste water except where noted.

Subcategory	BPCTCA max. avg. of 30 consecutive days	BPCTCA max. for any one day	BATEA and NSPS max. avg. of 30 consecutive days	BATEA and NSPS max. for any one day
Dimension stone, Crushed stone, & Construction Sand and Gravel	No discharge		No discharge	
Mine drainage		TSS 30 mg/l		TSS 30 mg/l
Industrial Sand				
Dry processing, Wet processing, & Non HF flotation	No discharge		No discharge	
HF flotation	TSS 0.044 kg/kkg F 0.005 kg/kkg	TSS 0.088 kg/kkg F 0.01 kg/kkg	No discharge	
Mine drainage		TSS 30 mg/l		TSS 30 mg/l
Gypsum				
Dry & Heavy Media Separation	No discharge		No discharge	
Wet Scrubbers	TSS 0.13 kg/kkg	TSS 0.26 kg/kkg	No discharge	
Mine drainage		TSS 30 mg/l		TSS 30 mg/l
Bituminous limestone, Oil-impregnated diatomite, Oilsonite, Asbestos, Wollostonite, Perlite, Pumice, Vermiculite, and expanded lightweight aggregates	No discharge		No discharge	
Mine drainage		TSS 30 mg/l		TSS 30 mg/l
Mica & Sericite				
Dry processing, Wet processing & Wet processing and general clay recovery	No discharge		No discharge	
Wet processing and Ceramic grade clay recovery	TSS 1.5 kg/kkg	TSS 3.0 kg/kkg	TSS 1.25 kg/kkg	TSS 2.5 kg/kkg
Mine drainage		TSS 30 mg/l		TSS 30 mg/l

pH 6-9 for all subcategories
No discharge - No discharge of process waste water pollutants
kg/kkg - kg of pollutant/kkg of product
BPCTCA - Best practicable control technology
BATEA - Best available technology economically achievable
NSPS - New source performance standard

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

The United States Environmental Protection Agency (EPA) is charged under the Federal Water Pollution Control Act Amendments of 1972 with establishing effluent limitations which must be achieved by point sources of discharge into the navigable water of the United States.

Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) to the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants. Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operating methods and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the minerals for the Construction Industry segment of minerals for the construction industry segment of the mineral mining and processing industry point source category. Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b) (1) (A) of the Act, to propose regulations establishing Federal standards of performances for new sources within such categories. The Administration published in the Federal Register of January 16, 1973 (38 F.R. 1624), a list of 27 source categories. Publication of an amended list will constitute announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the mineral mining and processing industry. The list will be amended when proposed regulations for the Mineral Mining and Processing Industry are published in the Federal Register.

SUMMARY OF METHODS

The effluent limitations guidelines and standards of performance proposed herein were developed in a series of systematic tasks. The mineral mining and processing industry was first studied to determine whether separate limitations and standards are appropriate for different segments within a point source category. Development of reasonable industry categories and subcategories, and establishment of effluent guidelines and treatment standards requires a sound understanding and knowledge of the mineral mining and processing industry, the processes involved, waste water generation and characteristics, and capabilities of existing control and treatment methods.

This report describes the results obtained from application of the above approach to the minerals for the construction industry segment of the mineral mining and processing industry. Thus, the survey and testing covered a wide range of processes, products, and types of wastes.

The products covered in this report are listed below with their SIC designations:

a. Dimension stone (1411)
b. Crushed stone (1422, 1423, 1429, 1499)
c. Construction sand and gravel (1442)
d. Industrial sand (1446)
e. Gypsum (1492)
f. Asphaltic Minerals (1499)
g. Asbestos and Wollastonite (1499)
h. Lightweight Aggregates (1499)
i. Mica and Sericite (1499)

Some of the above minerals which are processed only (3295) are also included.

Categorization and Waste Load Characterization

The effluent limitation guidelines and standards of performance proposed herein were developed in the following manner. The point source category was first categorized for the purpose of determining whether separate limitations and standards are appropriate for different segments within a point source category. Such subcategorization was based upon raw material used, product produced, manufacturing process employed, and other factors. The raw wastes characteristics for each subcategory were then identified. This included an analysis of (1) the source and volume of water used in the process employed and the sources of waste and waste waters at the facility; and (2) the constituents of all waste waters including harmful pollutants and other constituents which could result in degradation of the receiving water. The pollutants of waste waters which should be subject to effluent limitations guidelines and standards of performance were identified.

Treatment and Control Technologies

The full range of control and treatment technologies existing within each subcategory was identified. This included an identification of each control and treatment technology, including both in-facility and end-of-process technologies, which are existent or capable of being designed for each subcategory. It also included an identification of the amount of pollutants (including thermal) and the characteristics of pollutants resulting from the application of each of the treatment control technologies. The problems, limitations, and reliability of each treatment and control technology were also identified. In addition, the non-water quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise and radiation were also identified. The energy requirements of each of the control and treatment technologies were identified as well as the cost of the application of such technologies.

Data Base

The data for identification and analyses were derived from a number of sources. These sources included EPA research information, published literature, qualified technical consultation, on-site visits and interviews at numerous mining and processing facilities throughout the U.S., interviews and meetings with various trade associations, and interviews and meetings with various regional offices of the EPA. All references used in developing the guidelines for effluent limitations and standards of performance for new sources reported herein are included in Section XIII of this report. Table 2 summarizes the data base for the various subcategories in this volume.

Facility Selection

The following selection criteria were developed and used for the selection of facilities.

Discharge effluent quantities

Facilities with lowest effluent quantities or the ultimate of no discharge of process generated waste water pollutants were selected. These facilities might have reuse of water, raw material recovery and recycling, or use of evaporation. The significant criterion was minimal waste added to effluent streams per weight of product manufactured.

Land utilization

The efficiency of land use was considered.

Air pollution and solid waste control

The facilities must have possessed overall effective air and solid waste pollution control where relevant in addition to water pollution control technology. Care was taken to insure that all facilities chosen have minimal discharges into the environment and that these sites do not exchange one form of pollution for another of the same or greater magnitude.

Effluent treatment methods and their effectiveness

Facilities selected shall have in use the best currently available treatment methods, operating controls, and operational reliability. Treatment methods considered included basic process modifications which significantly reduce effluent loads as well as conventional treatment methods.

Facility facilities

All facilities chosen had all the facilities normally associated with the production of the specific product(s) in question. Typical facilities generally were facilities which have all their normal process steps carried out on-site.

TABLE 2

DATA BASE

		No Plants		
Subcategory	No. Plants	Visited	Data Available	Sampled
Dimension Stone	194	20	20	5
Crushed Stone				
Dry	1,800	5	52	*
Wet	2,700	26	130	9
Flotation	10	2	3	1
Shell Dredging	50	4	4	0
Construction Sand Gravel				
Dry	750	0	50	*
Wet	4,250	46	100	15
Dredging (on-land)	50	8	15	0
Dredging (on-board)	100	3	25	0
Industrial Sand				
Dry	20	0	5	*
Wet	130	3	10	2
Flotation (Acid & Alkaline)	17	4	10	2
Flotation (HF)	1	1	1	1
Gypsum				
Dry	73	5	54	2
Wet Scrubbing	5	1	8	1
HMS	2	1	2	*
Asphaltic Minerals				
Bituminous Limestone	2	0	2	*
Oil Impreg.Diatomite	1	1	1	*
Gilsonite	1	1	1	1
Asbestos				
Dry	4	2	4	1
Wet	1	1	1	*
Wollastonite	1	1	1	*
Lightweight Aggregates				
Perlite	13	4	4	*
Pumice	7	2	7	
Vermiculite	2	2	2	*
Mica & Sericite				
Dry	7	5	7	*
Wet	3	2	3	*
Wet Beneficiation	7	5	7	*
TOTAL	10,201	155	529	40

* There is no discharge of process waste water in this subcategory under normal operating conditions.

Facility management philosophy

Facilities were preferred whose management insists upon effective equipment maintenance and good housekeeping practices. These qualities are best identified by a high operational factor and facility cleanliness.

Geographic location

Factors which were considered include facilities operating in close proximity to sensitive vegetation or in densely populated areas. Other factors such as land availability, rainfall, and differences in state and local standards were also considered.

Raw materials

Differences in raw materials purities were given strong consideration in cases where the amounts of wastes are strongly influenced by the purity of raw materials used. Several facilities using different grades of raw materials were considered for those minerals for which raw material purity is a determining factor in waste control.

Diversity of processes

On the basis that all of the above criteria are met, consideration was given to installations having a multiplicity of manufacturing processes. However, for sampling purposes, the complex facilities chosen were those for which the wastes could be clearly traced through the various treatment steps.

Production

On the basis that other criteria are equal, consideration was given to the degree of production rate scheduled on water pollution sensitive equipment.

Product purity

For cases in which purity requirements play a major role in determining the amounts of wastes to be treated and the degree of water recycling possible, different product grades were considered for subcategorization.

GENERAL DESCRIPTION OF INDUSTRY BY PRODUCT

The materials categorized in SIC groups 141, 142, 144, industry code 1492, and select minerals in code 1499, have much in common in terms of their occurrence, mining and processing methods, and end product use.

General processing for crushed and broken stone includes quarrying or mining, crushing of oversize, and sizing of the crushed material. Use of crushed stone by the construction industry accounts for over 50 percent of crushed stone consumption. Other uses include manufactured fine aggregate and lime manufacture. The degree of material processing is dependent on customer demand. Dimension stone is quarried or mined in block form and requires special saws and equipment for dressing the finished stone. Monumental granite is the largest use category, in terms of value.

Sand and gravel is quarried or hydraulically mined, the oversize is crushed, sand and gravel separated by water, gravel sized and sand hydraulically classified. Over 90 percent of sand and gravel consumption is by the construction industry. Industrial sand is quarried or mined, the oversize is crushed, impurities are washed out, milled, graded according to size, and dried. Glass sand is generally beneficiated by flotation to yield a low iron content product. Predominant uses for industrial sand include glassmaking, molding, and foundry sand, all important to the construction industry. Gypsum is quarried or mined, the oversize is crushed, and milled into "land plaster." Most "land plaster" is calcined and processed into gypsum board products for use by the construction industry. Asphaltic minerals are usually extracted from an open pit, crushed, sized, and sold as a substitute for synthetic asphalt products. Asbestos is quarried or mined, the oversize is crushed, dried, and air classified into specific fiber lengths. Asbestos is used as an insulator and fireproofing material in the construction industry. Lightweight aggregates are either quarried or expanded into lightweight construction materials. Mica is mined, beneficiated, and ground into insulation or filler material used in the construction and electrical industries.

The 1972 production and employment figures for the industries mining and processing minerals for the construction industry were derived either from the Bureau of the Census (U.S. Department of Commerce) publications or the Commodity Data Summaries (1974) Appendix I to Mining and Minerals Policy, Bureau of Mines, U.S. Department of the Interior. These figures are tabulated in Table 3.

DIMENSION STONE (SIC 1411)

Rock which has been specially cut or shaped for use in buildings, monuments, memorial and gravestones, curbing, or other construction or special uses is called dimension stone. Large quarry blocks suitable for cutting to specific dimensions are also classified as dimension stone. The principal dimension stones are granite, marble, limestone,

TABLE 3

1972 Production and Employment Figures for the Industries Mining and Processing Minerals for the Construction Industry

SIC Code	Product	1972 Production		Employment
		1000 kkg	1000 tons	
1411	Dimension stone-limestone	542	598	2,000 combined SIC 1411
1411	Dimension stone-granite	357	394	
1411	Dimension stone-other*	559	616	
1422	Crushed & broken stone-limestone	542,400	598,000	29,400
1423	Crushed & broken stone granite	95,900	106,000	4,500
1429	Crushed & broken stone NEC	113,000	124,600	7,400
1499	Crushed & broken stone shell	19,000	(20,900)	Unknown
1442	Construction sand & gravel	650,000	717,000	30,300
1446	Industrial sand	27,120	29,999	4,400
1492	Gypsum	11,200	12,330	2,900
1499	Bituminous Limestone	1,770	1,950	Unknown
1499	Oil-impregnated diatomite	109	120	Unknown
1499	Gilsonite	45	50	Unknown
1499	Asbestos	120	132	400
1499	Wollastonite	63	70	70
1499	Perlite	589	649	100
1499	Pumice	3,460	3,810	525
1499	Vermiculite	306	337	225
1499	Mica	145	160	75

* Sandstone, marble, et al

slate, and sandstone. Less common are diorite, basalt, mica schist, quartzite, diabase and others.

Terminology in the dimension stone industries is somewhat ambiguous and frequently does not correspond to the same terms used in mineralogical rock descriptions. Dimension granites include not only true granite, but many other types of igneous and metamorphic rocks such as quartz diorites, syenites, quartz porphyries, gabbros, schists, and gneisses. Dimension marble may be used as a term to describe not only true marbles, which are metamorphosed limestones, but also any limestone that will take a high polish. Many other rocks such as serpentines, onyx, travertines, and some granites are frequently called marble by the dimension stone industry. Hard cemented sandstones are sometimes called quartzite although they do not specifically meet the mineralogical definition.

Many of the continental United States possess dimension stone of one kind or other, and many have one or more producing operations. However, only a few have significant operations. These are as follows:

Granite - Minnesota
- Georgia
- Vermont
- Massachusetts
- South Dakota

Marble - Georgia
- Vermont
- Minnesota (dolomite)

Limestone - Indiana
- Wisconsin

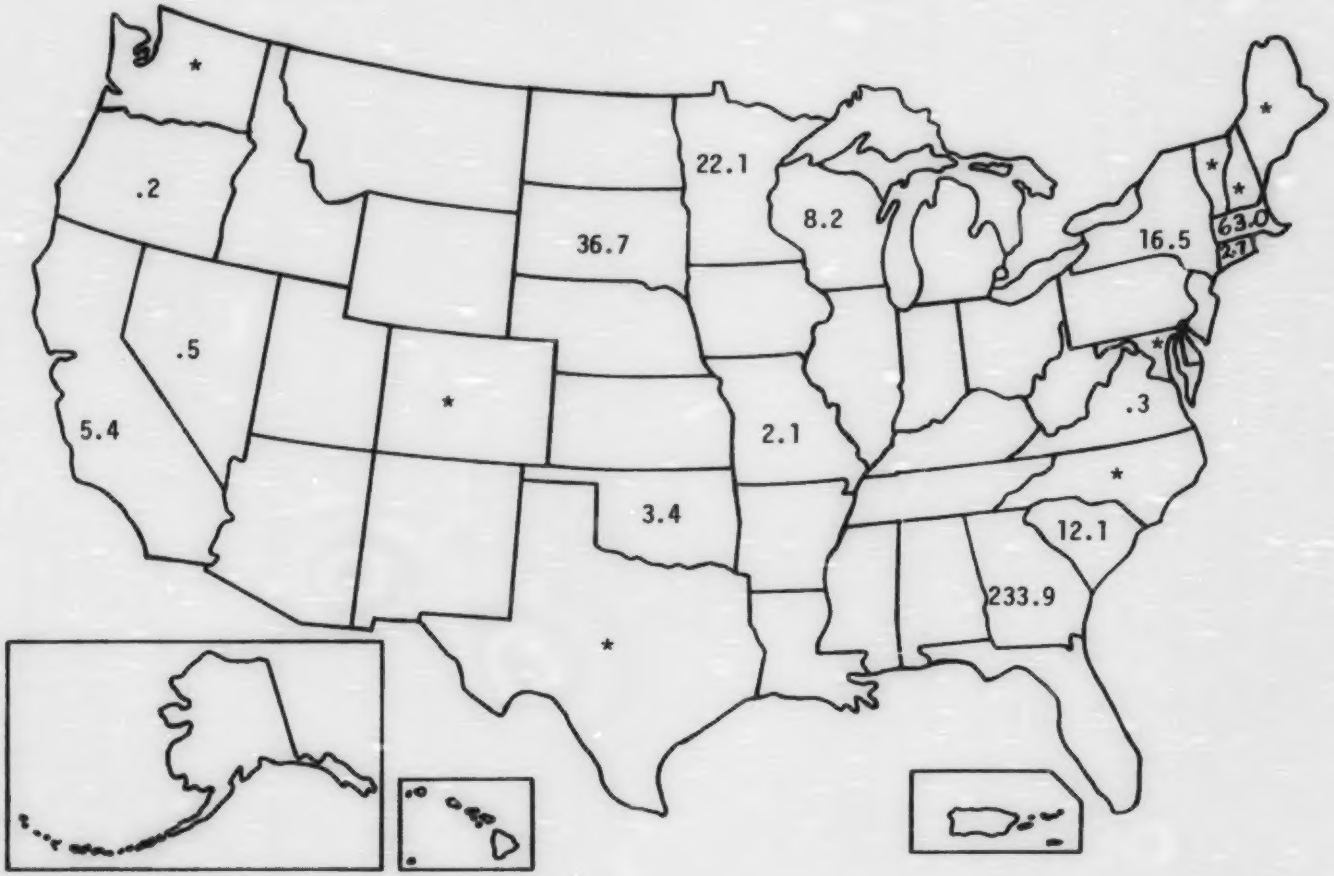
Slate - Vermont
- New York
- Virginia
- Pennsylvania

Sandstone, Quartz, and Quartzite - Ohio, Pennsylvania, and New York

Figures 1, 2 and 3 give the U. S. production on a state basis for granite, limestone and sandstone, quartz and quartzite respectively the principal stones quarried as shown in Table 4. There are less than 500 dimension stone mining activities in the U.S. Present production methods for dimension stone range from the inefficient antiquated to the technologically modern. Quarrying methods include use of various combinations of wire saws, jet torches, channeling machines, drilling machines, wedges, and

FIGURE 1.

DIMENSIONAL GRANITE
1972/1000 short tons

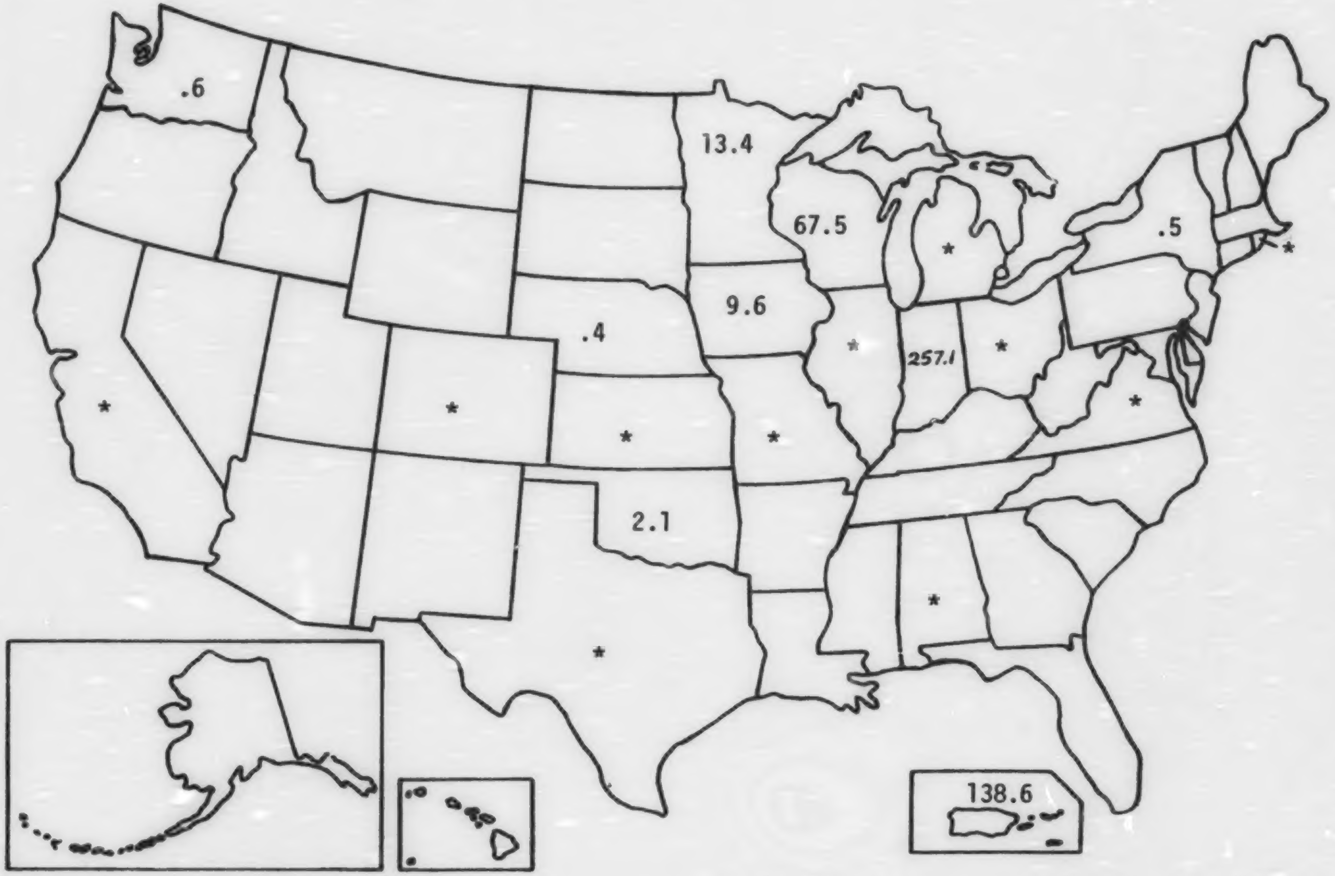


* Producing States (total = 214.0)
National Total = 621.2

Data From: Minerals Yearbook - 1972, Vol. I
Table 5, p. 1164

FIGURE 2

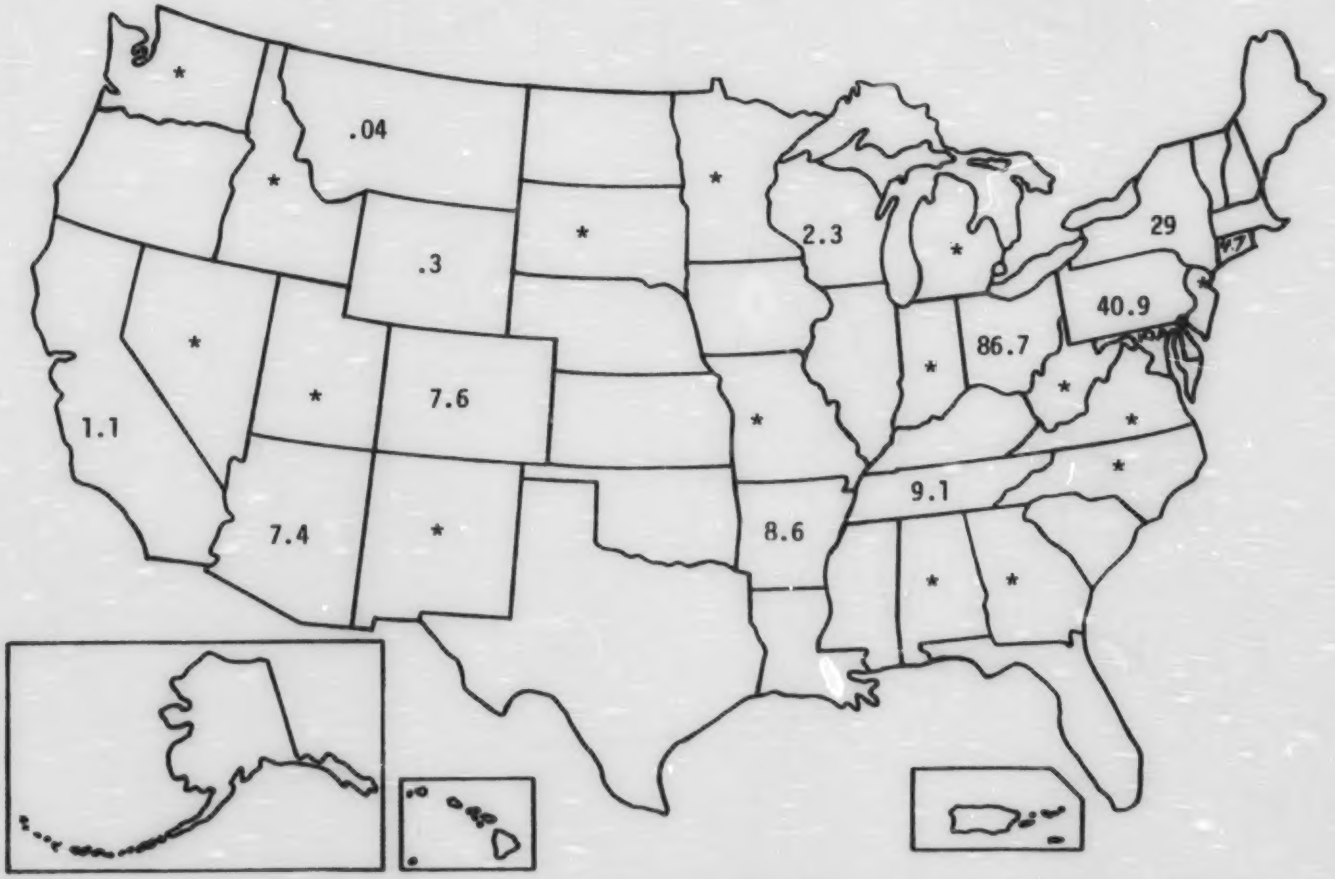
DIMENSIONAL LIMESTONE
1972/1000 short tons



* Producing States (Total = 54.8)
National Total = 411.1 (excluding P.R.)

Data From: Minerals Yearbook - 1972, Vol. I
Table 6, p. 1164

FIGURE 3
DIMENSIONAL SANDSTONE,
QUARTZ, QUARTZITE
1972/1000 short tons



* Producing States (Total = 22.3)
National Total = 230.7

Data From: Minerals Yearbook - 1972, Vol I
Table 7, p. 1165

Table 4

DIMENSION STONE SHIPPED OR USED BY PRODUCERS IN THE UNITED STATES, BY USE AND KIND OF STONE (1972)

Kind of stone and use	1000 short tons
GRANITE	
Rough:	
Architectural	46
Construction	54
Monumental	287
Other rough stone	--
Dressed:	
Cut	--
Sawed	14
House stone veneer	6
Construction	10
Monumental	33
Curbing	130
Flagging	--
Paving blocks	--
Other dressed stone	42
Total	621
Value ($1000)	42,641
LIMESTONE AND DOLOMITE	
Rough:	
Architectural	175
Construction	56
Flagging	18
Other rough stone	1
Dressed:	
Cut	49
Sawed	30
House stone veneer	68
Construction	12
Flagging	2
Other dressed stone	1
Total	411
Value ($1000)	14,378
MARBLE	
Rough: Architectural	9
Dressed:	
Cut	21
Sawed	5
House stone veneer	9
Construction and Monumental	27
Total	71
Value ($1000)	16,541
SANDSTONE, QUARTZ & QUARTZITE	
Rough:	
Architectural	42
Construction	74
Flagging	18
Other rough stone	1
Dressed:	
Cut	21
Curbing	--
Sawed	--
House stone veneer	27
Flagging	17
Other uses not listed	32
Total	231
Value ($1000)	7,684
SLATE	
Roofing slate	12
Millstock:	
Structural and sanitary	14
Blackboards, etc	1
Billiard table tops	4
Total	19
Flagging	36
Other uses not listed	14
Total	80
Value ($1000)	7,404
OTHER STONE	
Rough:	
Architectural	14
Construction	43
Dressed:	
Cut	2
Construction	4
Flagging	--
Structural and sanitary purposes	--
Total	66
Value ($1000)	1,964
TOTAL STONE	
Rough:	
Architectural	286
Construction	239
Monumental	287
Flagging	36
Other rough stone	2
Dressed:	
Cut	117
Sawed	65
House stone veneer	110
Construction	32
Roofing (slate)	12
Millstock (slate)	19
Monumental	65
Curbing	130
Flagging	61
Other uses not listed	31
Total	1,490
Value ($1000)	90,763

Minerals Yearbook, 1972, U.S. Department of the Interior, Bureau of Mines broaching tools. The choice of equipment mix depends on the type of dimension stone, size and shape of deposit, production capacity, labor costs, financial factors, and management attitudes.

Blasting with a low level explosive such as black powder, is occasionally used. Blocks cut from the face are sawed or split into smaller blocks for ease in transportation and handling. The blocks are taken to processing facilities, often located at the quarry site, for final cutting and finishing operations. Stone finishing equipment includes: (a) gang saws (similar to large hack saws), used with water alone, or water with silicon carbide (SiC) abrasive added, and recently, with industrial diamond cutting edges; (b) wire saws used with water alone, or with water and quartz sand, or water with SiC; (c) diamond saws; (d) profile grinders; (e) guillotine cutters; (f) pneumatic actuated cutting tools (chisels); (g) sand blasting, shot peening; and (h) polishing mills.

CRUSHED STONE (SIC 1422, 1423 and 1429)

This stone category pertains to rock which has been reduced in size after mining to meet various consumer requirements. As with dimension stone, the terminology used by the crushed stone producing and consuming industries is not consistent with mineralogical definitions. Usually all of the coarser grained igneous rocks are called granite. The term traprock pertains to all dense, dark, and fine-grained igneous rocks. Quartzite may describe any siliceous-cemented sandstone whether or not it meets the strict mineralogical description. As the table that follows shows approximately three-fourths of all crushed stone is limestone or limestone-dolomite.

PRODUCTION OF ROCK TYPE

Kind of Stone	1972 1000 Short Tons	Percent
Granite	106,266	11.5
Traprock	80,462	8.7
Marble	2,247	0.2
Limestone and Dolomite	671,496	72.8
Shell	16,610	1.8
Calcareous Marl	2,650	0.3
Sandstone, Quartz and Quartzite	27,817	3.0
Other	298	1.6
Total	922,361	

Riprap is large irregular stone used chiefly in river and harbor work and to protect highway embankments. Fluxing stone is limestone, usually 4 to 6 inches in size, which is used to form slag in blast furnaces and other metallurgical processes. Terrazzo is sized material, usually marble or limestone, which is mixed with cement for pouring floors, which are smoothed down to expose the chips after the floor has hardened. A small amount of quartzose rock is also used for flux. Stucco dash consists of white or brightly colored stone, 1/8 to 3/8 inches in size, for use in stucco facing. The ability of ground limestone to significantly reduce the acidity of soils has resulted in its widespread use in agricultural processes.

The crushed stone industry is widespread and varied in size of facilities and types of material produced. The size of individual firms varies from small independent producers with single facilities to large diversified corporations with 50 or more crushed stone facilities as well as other important interests. Facility capacities range from less than 22,700 kkg/yr (25,000 tons/yr) to about 13.6 million kkg/yr (15 million tons/yr). As Table 5 shows only about 5.2 percent of the commercial facilities are of a 816,000 kkg (900,000 ton) capacity or larger, but these account for 39.5 percent of the total output. At the other extreme, facilities of less than 22,700 kkg (25,000 ton) annual capacity made up 33.3 percent of the total number but produce only 1.3 percent of the national total. Geographically, the facilities are widespread with all States reporting production. In general, stone output of the individual States correlates with population and industrial activity as shown by Figures 4 and 5. This is true because of the large cost of shipment in relation to the value of the crushed stone.

Most crushed and broken stone is presently mined from open quarries, but in many areas factors favoring large-scale production by underground mining methods are becoming more frequent and more prominent. Surface mining equipment varies with the type of stone, the production capacity needed, size and shape of deposits, estimated life of the operation, location of the deposit with respect to urban centers, and other important factors. Ordinarily, drilling is done with tricone rotary drills, long-hole percussion drills including "down the hole" models, and churn drills. Blasting in smaller operations may still be done with dynamite, but in most sizable operations ammonium nitrate-fuel oils mixtures (AN/FO), which are much lower in cost, are used. Secondary breakage increasingly is done with mechanical equipment such as drop hammers to minimize blasting in urban and residential areas.

TABLE 5

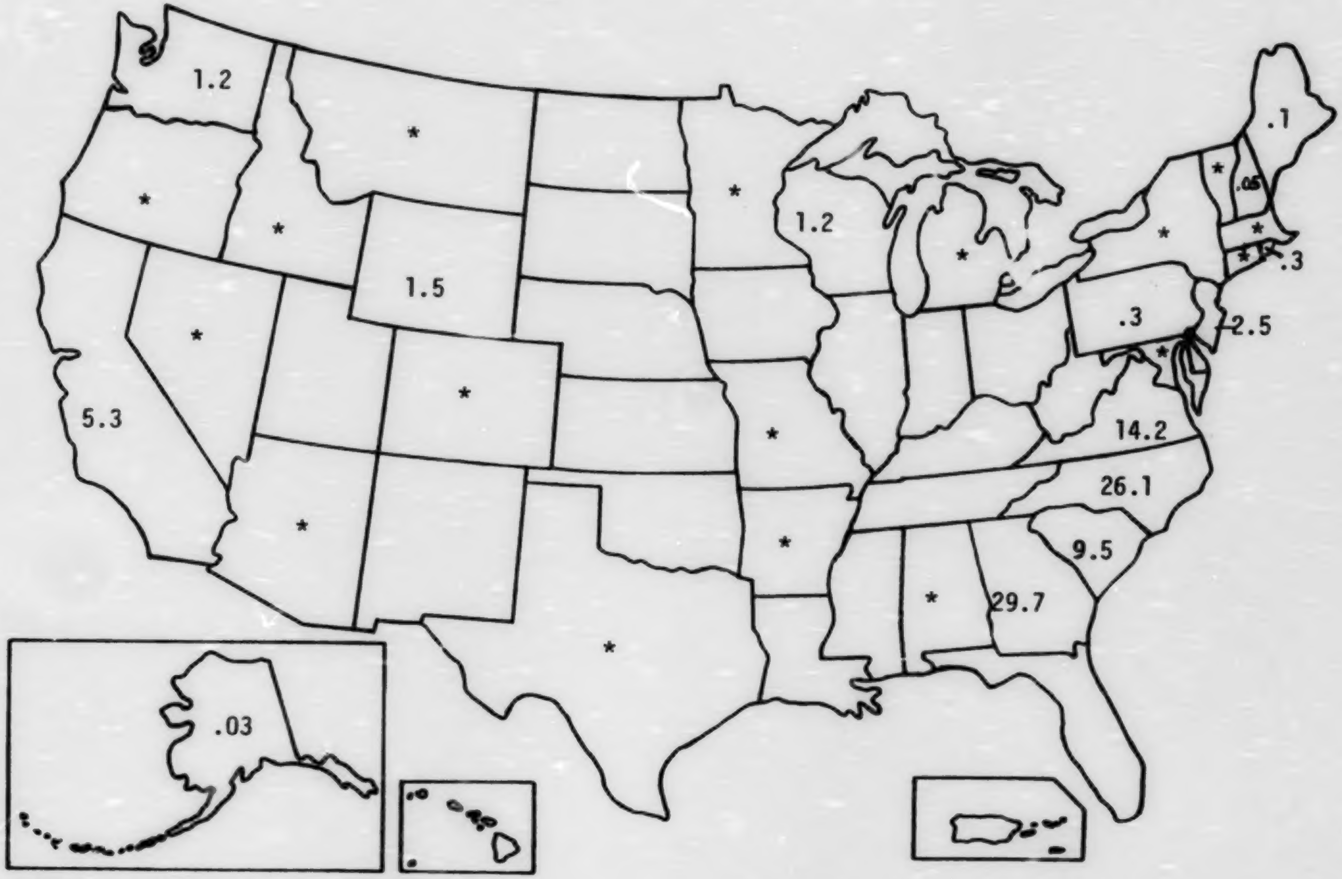
1973 SIZE DISTRIBUTION OF CRUSHED STONE PLANTS*

ANNUAL PRODUCTION TONS	NUMBER OF QUARRIES	TOTAL ANNUAL PRODUCTION 1000 TONS	PERCENT OF TOTAL
6 25,000	1,600	13,603	1.3
25,000 - 49,999	600	24,221	2.3
50,000 - 74,999	339	20,485	1.9
75,000 - 99,999	253	21,941	2.1
100,000 - 199,999	634	90,974	8.6
200,000 - 299,999	308	75,868	7.2
300,000 - 399,999	233	80,946	7.6
400,000 - 499,999	182	80,956	7.7
500,000 - 599,999	126	68,903	6.5
600,000 - 699,999	98	62,730	5.9
700,000 - 799,999	76	56,694	5.4
800,000 - 899,999	51	42,718	4.0
6 900,000	248	418,502	39.5
TOTAL	4,808	1,058,541	100.0

* U.S. Deaprtment of the Interior
Bureau of Mines
Division of Nonmetallic Minerals

FIGURE 4

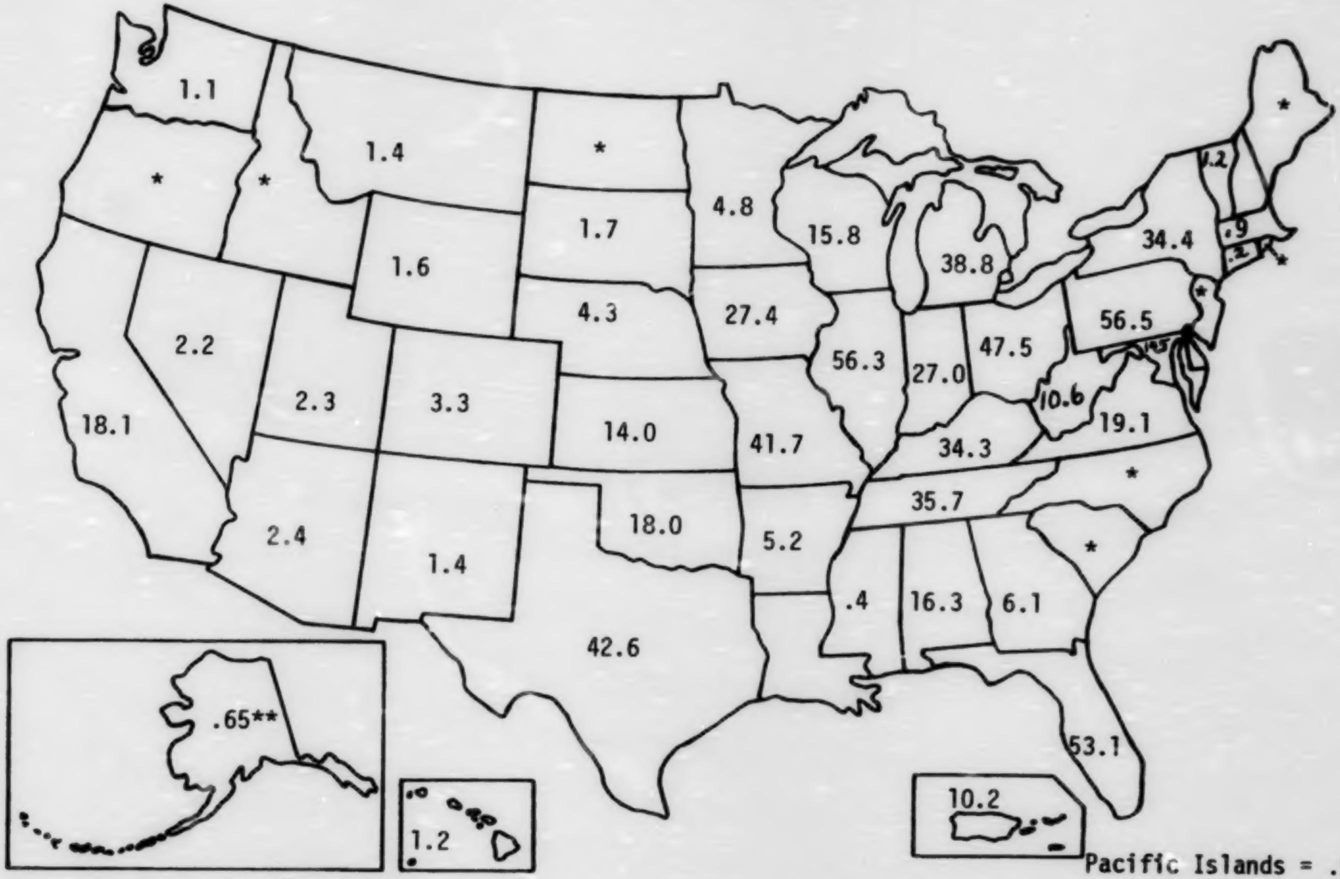
CRUSHED GRANITE
1972/1,000,000 short tons



* Other producing States (total = 13.9)
National Total = 106.3

Data From: Minerals Yearbook - 1972, Vol. I
Table 11, p. 1168

FIGURE 5
CRUSHED LIMESTONE
AND DOLOMITE
1972/1,000,000 short tons



Pacific Islands = .9

** Total stone - crushed & dimensional
* Other producing States (total = 8.2)
National total (excluding P.R. & territories) = 663.3

Data From: Mineral Yearbook - 1972, Vol. I
Table 13, p. 1170

Underground operations are becoming more common as the advantages of such facilities increase or are increasingly recognized by the producers. Underground mines can be operated on a year-round, uninterrupted basis; do not require extensive removal of overburden; do not produce much if any waste requiring subsequent disposal; require little surface area which becomes of importance in areas of high land cost and finally, greatly reduce the problems of environmental disturbance and those of rehabilitation of mined-out areas. An additional benefit from underground operations, as evidenced in the Kansas City area, is the value of the underground storage space created by the mine - in many cases the sale or rental of the space produces revenue exceeding that from the removal of the stone.

Loading and hauling equipment has grown larger as increasing demand for stone has made higher production capacities necessary. Track-mounted equipment is still used extensively but pneumatic-tire-mounted hauling equipment is predominant.

Crushing and screening facilities have become larger and more efficient, and extensive use is made of belt conveyors for transfer of material from the pits to the loading-out areas. Bucket elevators are used for lifting up steep inclines. Primary crushing is often done at or near the pit, usually by jaw crushers or gyratories, but impact crushers and special types may be used for nonabrasive stone, and for stone which tends to clog the conventional crushers. For secondary crushing a variety of equipment is used depending on facility size, rock type, and other factors. Cone crushers and gyratories are the most common types. Impact types including hammer mills are often used where stone is not too abrasive. For fine grinding to produce stone sand, rod mills predominate.

For screening, inclined vibrating types are commonly used in permanent installations, while horizontal screens, because they require less space, are used extensively in portable facilities. For screening large sizes of crushed stone, heavy punched steel plates are used, while woven wire screens are used for smaller material down to about one-eighth of an inch. Air and hydraulic separation and classifying equipment is ordinarily used for the minus 1/8 inch material.

Storage of finished crushed stone is usually done in open areas except for the small quantities that go to the load-out bins. In the larger and more efficient facilities the stone is drawn out from tunnels under the storage piles, and the equipment is designed to blend any desired mixture of sizes that may be needed.

Oyster shells are found in shallow waters in great quantity, and, being made of very pure calcium carbonate, they are dredged for use in the manufacture of lime and cement. The industry is large and active along the Gulf Coast, especially at New Orleans, Lake Charles, Houston, Freeport, and Corpus Christi.

In Florida, oyster shell was recovered from fossil beds offshore on both Atlantic and Gulf coasts. Production in 1957 amounted to 1,364,000 kkg (1,503,964 tons), used principally for road metal and a small amount as poultry grit. This figure included coquina, a cemented shell rock of recent but not modern geological time, which is dredged for the manufacture of cement near Bunnell in Flagler County. It is used widely on lightly traveled sand roads along the east coast.

Clam shells used to be dredged from fresh water streams in midwestern states for the manufacture of buttons, but the developments in the plastics industry have impacted heavily.

Table 6 gives a breakdown of the end uses of crushed stone. The majority of crushed stone is used in road base, cement and concrete.

CONSTRUCTION SAND AND GRAVEL (SIC 1442)

Sand and gravel are products of the weathering of rocks and thus consist predominantly of silica but often contain varying amounts of other minerals such as iron oxides, mica and feldspar. The term sand is used to describe material whose grain size lies within the range of 0.065 and 2 mm and which consists primarily of silica but may also include fine particles of any rocks, minerals and slags. Gravel consists of naturally occurring rock particles larger than about 4 mm but less than 64 mm in diameter. Although silica usually predominates in gravel, varying amounts of other rock constituents such as mica, shale, and feldspar are often present. Silt is a term used to describe material finer than sand, while cobbles and boulders are larger than gravel. The term "granules" describes material in the 2 to 4 mm size range. The descriptive terms and the size ranges are somewhat arbitrary although standards have to some extent been accepted. For most applications of sand and gravel there are specifications for size, physical characteristics, and chemical composition. For construction uses, the specifications depend on the type of construction - roads (concrete or bituminous), dams, and buildings - the geographic area, architectural standards, climate, and the type and quality of sand and gravel available.

Table 6
1972 Uses of Crushed Stone

Kind of stone and use	Quantity (1000 tons)
CALCAREOUS MARL	
Agricultural purposes	133
Cement manufacture	2,517
Other uses	--
Total	2,650
Value ($1000)	3,598
GRANITE	
Agricultural purposes	--
Concrete aggregate (coarse)	18,579
Bituminous aggregate	16,088
Macadam aggregate	3,966
Dense graded road base stone	37,877
Surface treatment aggregate	5,696
Unspecified construction aggregate and roadstone	10,048
Riprap and jetty stone	4,036
Railroad ballast	6,162
Filter stone	--
Fill	97
Other uses	3,718
Total	106,266
Value ($1000)	182,930
LIMESTONE AND DOLOMITE	
Agricultural purposes	27,140
Concrete aggregate (coarse)	100,173
Bituminous aggregate	49,977
Macadam	26,993
Dense graded road base stone	139,257
Surface treatment aggregate	38,704
Unspecified construction aggregate and roadstone	71,647
Riprap and jetty stone	12,935
Railroad ballast	7,250
Filter stone	339
Manufactured fine aggregate (stone sand)	4,752
Terrazzo and exposed aggregate	124
Cement manufacture	101,304
Lime manufacture	28,858
Dead-burned dolomite	1,670
Ferrosilicon	1,030
Flux stone	24,728
Refractory stone	395
Chemical stone for Alkali Works	4,199
Special uses and products	876
Mineral fillers, extenders, and whiting	2,984
Chemicals	635
Fill	4,243
Glass	1,794
Sugar refining	560
Other uses	18,930
Total	671,496
Value ($1000)	1,090,707
MARBLE	
Agricultural purposes	44
Macadam aggregate	83
Concrete aggregate (coarse)	--
Dense graded road base stone	--
Unspecified construction aggregate and roadstone	862
Riprap and jetty stone	--
Filter stone	--
Manufactured fine aggregate (stone sand)	--
Terrazzo and exposed aggregate	203
Mineral fillers, extenders, and whiting	1,047
Other uses	8
Total	7,247
Value ($1000)	25,005
SANDSTONE, QUARTZ, AND QUARTZITE	
Concrete aggregate (coarse)	2,092
Bituminous aggregate	1,613
Macadam aggregate	351
Dense graded road base stone	8,744
Surface treatment aggregate	951
Unspecified construction aggregate and roadstone	3,290
Riprap and jetty stone	2,213
Railroad ballast	1,014
Filter stone	52
Manufactured fine aggregate (stone sand)	343
Terrazzo and exposed aggregate	23
Cement and lime manufacture	522
Ferrosilicon	227
Flux stone	1,102
Refractory stone	211
Abrasives	45
Glass	925
Other uses	3,100
Total	26,817
Value ($1000)	57,994
SHELL	
Concrete aggregate (coarse)	--
Dense graded road base stone	1,675
Unspecified construction aggregate and roadstone	3,281
Cement and lime manufacture	5,675
Other uses	5,98[illegible]
Total	16,610
Value ($1000)	29,571
TRAPROCK	
Agricultural purposes	444
Concrete aggregate (coarse)	6,643
Bituminous aggregate	11,469
Macadam aggregate	1,438
Dense graded road base stone	19,361
Surface treatment aggregate	5,341
Unspecified construction aggregate and roadstone	23,811
Riprap and jetty stone	3,623
Railroad ballast	2,332
Filter stone	117
Manufactured fine aggregate (stone sand)	231
Fill	1,686
Other uses	3,966
Total	80,462
Value ($1000)	170,823
OTHER STONE	
Concrete aggregate (coarse)	1,159
Bituminous aggregate	2,202
Macadam aggregate	278
Dense graded raod base stone	3,051
Surface treatment aggregate	591
Unspecified construction aggregate and roadstone	2,911
Riprap and jetty stone	1,738
Railroad ballast	--
Mineral fillers, extenders and whiting	--
Fill	578
Other uses	1,789
Total	14,298
Value ($1000)	24,442
TOTAL STONE	
Agricultural purposes	23,393
Concrete aggregate (coarse)	133,471
Bituminous Aggregate	82,560
Macadam aggregate	33,110
Dense graded road base stone	210,013
Surface treatment aggregate	51,943
Unspecified construction aggregate and roadstone	113,406
Riprap and jetty stone	24,560
Railroad ballast	18,021
Filter stone	636
Manufactured fine aggregate (stone sand)	5,869
Terrazzo and exposed aggregate	402
Cement manufacture	108,857
Lime manufacture	30,051
Dead-burned dolomite	1,670
Ferrosilicon	1,257
Flux stone	25,830
Refractory stone	605
Chemical stone for alkali works	4,199
Special uses and products	1,071
Mineral fillers, extenders and whiting	4,423
Fill	6,630
Glass	2,718
Expanded slate	1,270
Other uses	31,394
Total	922,361
Value ($1000)	1,592,569

Minerals Yearbook, 1972, U.S. Department of the Interior
Bureau of Mines

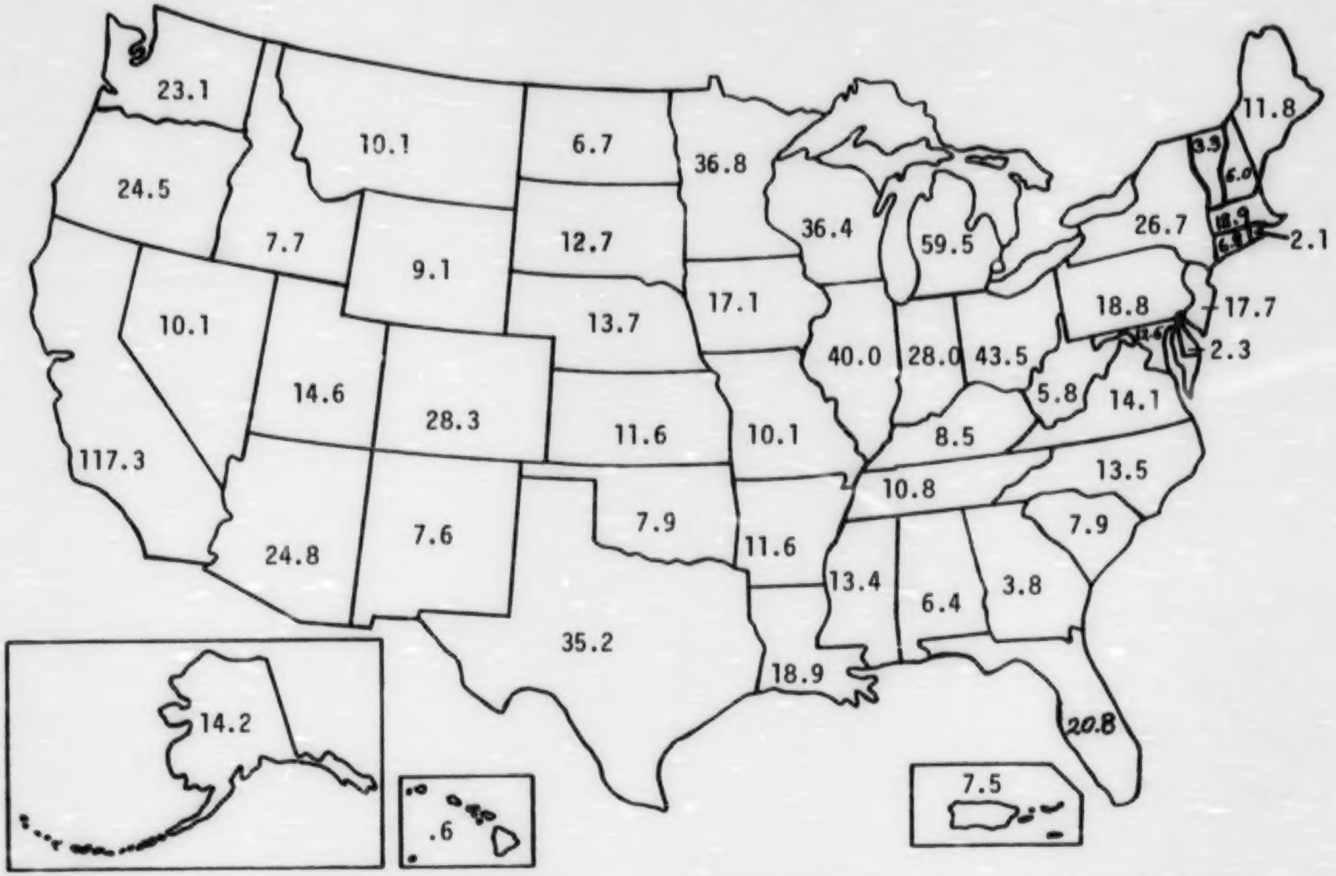
Briefly, on a geographic-geologic basis, in the glaciated areas in the northern States, and for a hundred miles or more south of the limit of glacial intrusion, the principal sand and gravel resources consist of various types of outwash glacial deposits and glacial till. Marine terraces, both ancient and recent geologically, are major sand and gravel sources in the Atlantic and Gulf Coastal Plains. River deposits are the most important sand and gravel sources in several of the Southeastern and South Central States. Abundant sand and gravel resources exist in the mountainous areas and the drainage from the mountains has created deposits at considerable distances from the initial sources. Great Plains sand and gravel resources consist mainly of stream-worked material from existing sediments. On the West Coast, deposits consist of alluvial fans, river deposits, terraces, beaches, and dunes. Figures 6 and 7 show the production and facility distribution for the United States.

The sand and gravel industry, on the basis of physical volume, is the largest nonfuel mineral industry; the value of sand and gravel output is exceeded by that of only one nonfuel mineral commodity, stone. Because of its widespread occurrence and the necessity for producing sand and gravel near the point of use there are more than 5,000 firms engaged in commercial sand and gravel output, with no single firm being large enough to dominate the industry. Facility sizes range from very small producers of pit-run material to highly automated permanent installations capable of supplying as much as 3.6 million kkg (4 million tons) yearly of closely graded and processed products; the average commercial facility capacity is about 108,000 kkg/yr (120,000 tons/yr). As seen from Table 7 about 40 percent of all commercial facilities are of less than 22,600 kkg (25,000 tons) capacity, but together these account for only 4 percent of the total commercial production. At the other extreme, commercial operations with production capacities of more than 907,000 kkg (1 million tons) account for less than 1 percent of the total number of facilities and for 12 to 15 percent of the commercial production.

Geographically the sand and gravel industry is concentrated in the large rapidly expanding urban areas and on a transitory basis, in areas where highways, dams, and other large-scale public and private works are under construction. Three-fourths of the total domestic output of sand and gravel is by commercial firms, and one-fourth by Government-and-contractor operations.

FIGURE 6

SAND AND GRAVEL
PRODUCTION
1972/1,000,000 short tons

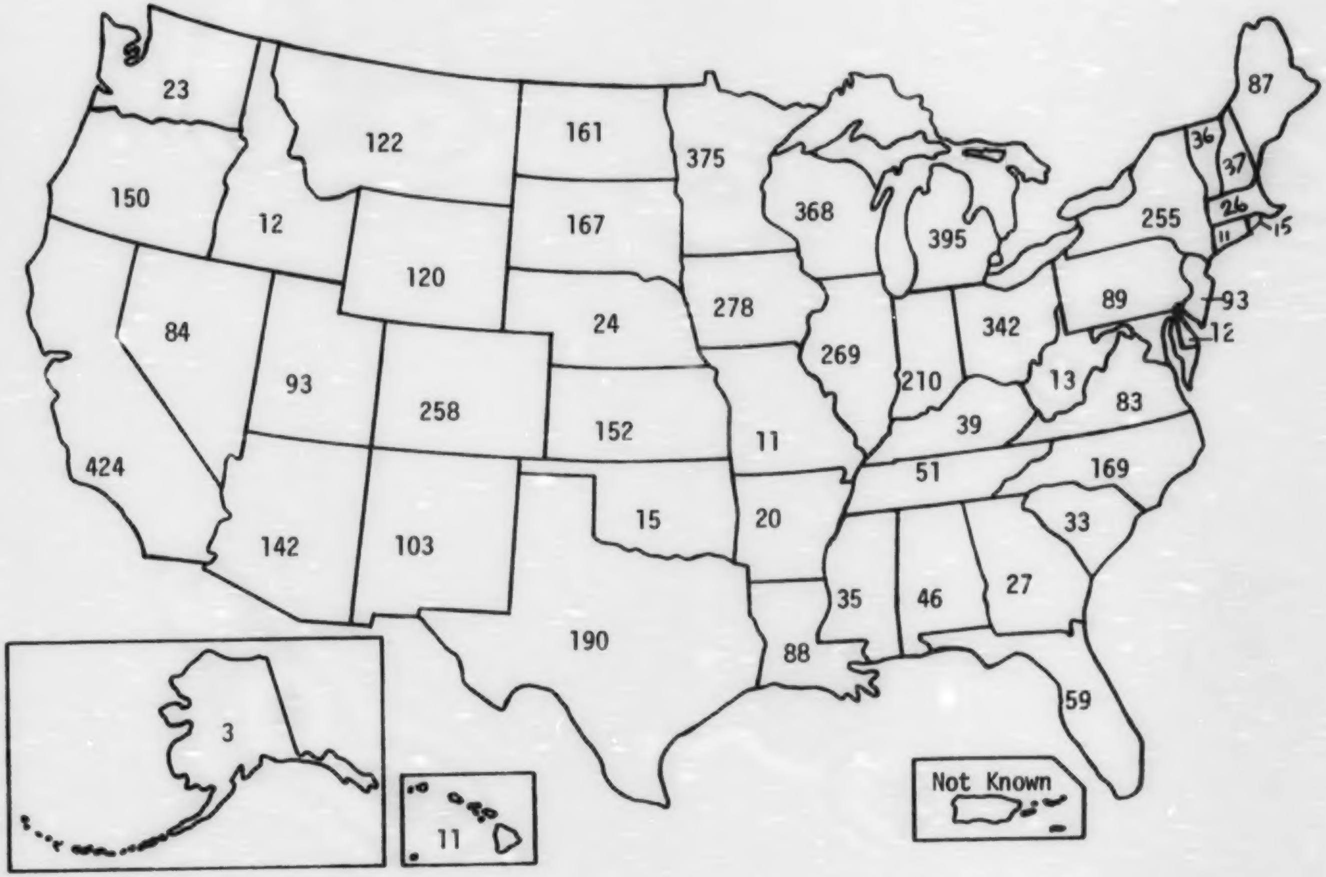


Data From: Minerals Yearbook - 1972, Vol. I
Table 3, p. 1111-1112
Bureau of Mines

National Total (excluding P.R.) = 913.2

FIGURE 7

SAND AND GRAVEL
PLANTS
1972



Data From: Minerals Yearbook - 1972
Vol II
Bureau of Mines

TABLE 7

1972 Size Distribution of Sand and Gravel Plants

Annual Production (short tons)	Plants Number	Production Thousand short tons	 Percent of total
Less than 25,000	1,630	17,541	2.2
25,000 to 50,000	850	30,508	3.9
50,000 to 100,000	957	68,788	8.8
100,000 to 200,000	849	121,304	15.4
200,000 to 300,000	400	97,088	12.4
300,000 to 400,000	217	75,157	9.6
400,000 to 500,000	134	59,757	7.6
500,000 to 600,000	79	42,924	5.5
600,000 to 700,000	71	46,036	5.9
700,000 to 800,000	56	41,860	5.3
800,000 to 900,000	26	22,310	2.8
900,000 to 1,000,000	27	25,666	3.3
1,000,000 and over	88	136,850	17.3
Total	5,384	785,788	100.0

Minerals Yearbook, 1972, U.S. Department of the Interior, Bureau of Mines, Vol I, page 1120

California leads in total sand and gravel production with output more than double that of any other State. Production for the State in 1968 was 113 million kkg (125 million tons), or 14 percent of the national total. Three of the 10 largest producing firms are located in California. The next five producing States with respect to total output all border on the Great Lakes, where ample resources, urban and industrial growth, and low-cost lake transportation are all favorable factors.

Mining equipment used varies from small, simple units such as tractor-mounted high-loaders and dump trucks to sophisticated mining systems involving large power shovels, draglines, bucket-wheel excavators, belt conveyors and other components. Increasingly, mining systems are being designed to provide for most efficient and economical subsequent land rehabilitation. Sand and gravel is also dredged from river and lake bottoms rich in such deposits.

Processing may consist of simple washing to remove clay and silt and screening to produce two or more products or it may involve more complex heavy medium separation of slate and other lightweight impurities, and complex screening and crushing equipment designed to produce the optimum mix of salable sand and gravel sizes. Conveyor belts, bucket elevators, and other transfer equipment are used extensively. Ball processing is often required for production of small-size fractions of sand. Permanent installations are built when large deposits are to be operated for many years. Semiportable units are used in many pits which have an intermediate working life. Several such units can be tied together to obtain large initial production capacity or to add capacity as needed. In areas where large deposits are not available, use is made of mobile screening facilities, which can be quickly moved from one deposit to another without undue interruption or loss of production. Table 8 breaks down the end uses of sand and gravel.

INDUSTRIAL SAND (SIC 1446)

Industrial sands includes those types of silica raw materials that have been segregated and refined by natural processes into nearly monomineralic deposits and hence, by virtue of their high degree of purity, have become the sources of commodities having special and somewhat restricted commercial uses. In some instances, these raw materials occur in nature as unconsolidated quartzose sand or gravel and can be exploited and used with very little preparation and expense. More often, they occur as sandstone, conglomerate quartzite, quartz mica schist, or massive igneous quartz which must be crushed, washed,

Table 8
1972 Uses of Sand and Gravel

Use	Quantity 1000 kkg	Quantity 1000 short tons
Building		
Sand	170,329	187,794
Gravel	139,001	153,254
Paving		
Sand	119,182	131,402
Gravel	254,104	280,159
Fill		
Sand	44,050	48,567
Gravel	39,416	43,458
Railroad Ballast		
Sand	948	1,045
Gravel	2,022	2,229
Other		
Sand	8,685	9,575
Gravel	11,682	12,880
Total	789,419	870,363
Value ($1000)		1,069,374
Value ($/Quantity)	1.35	1.23

Minerals Yearbook, 1972, U.S. Department of the Interior
Bureau of Mines

screened, and sometimes chemically treated before commodities of suitable compositional and textural characteristics can be successfully prepared.

Industrial silica used for abrasive purposes falls into three main categories: (a) blasting sand; (b) glass-grinding sand; and (c) stonesawing and rubbing sand.

Figure 8 locates the domestic industrial sand deposits. Table 9 gives the breakdown of the uses of industrial sand.

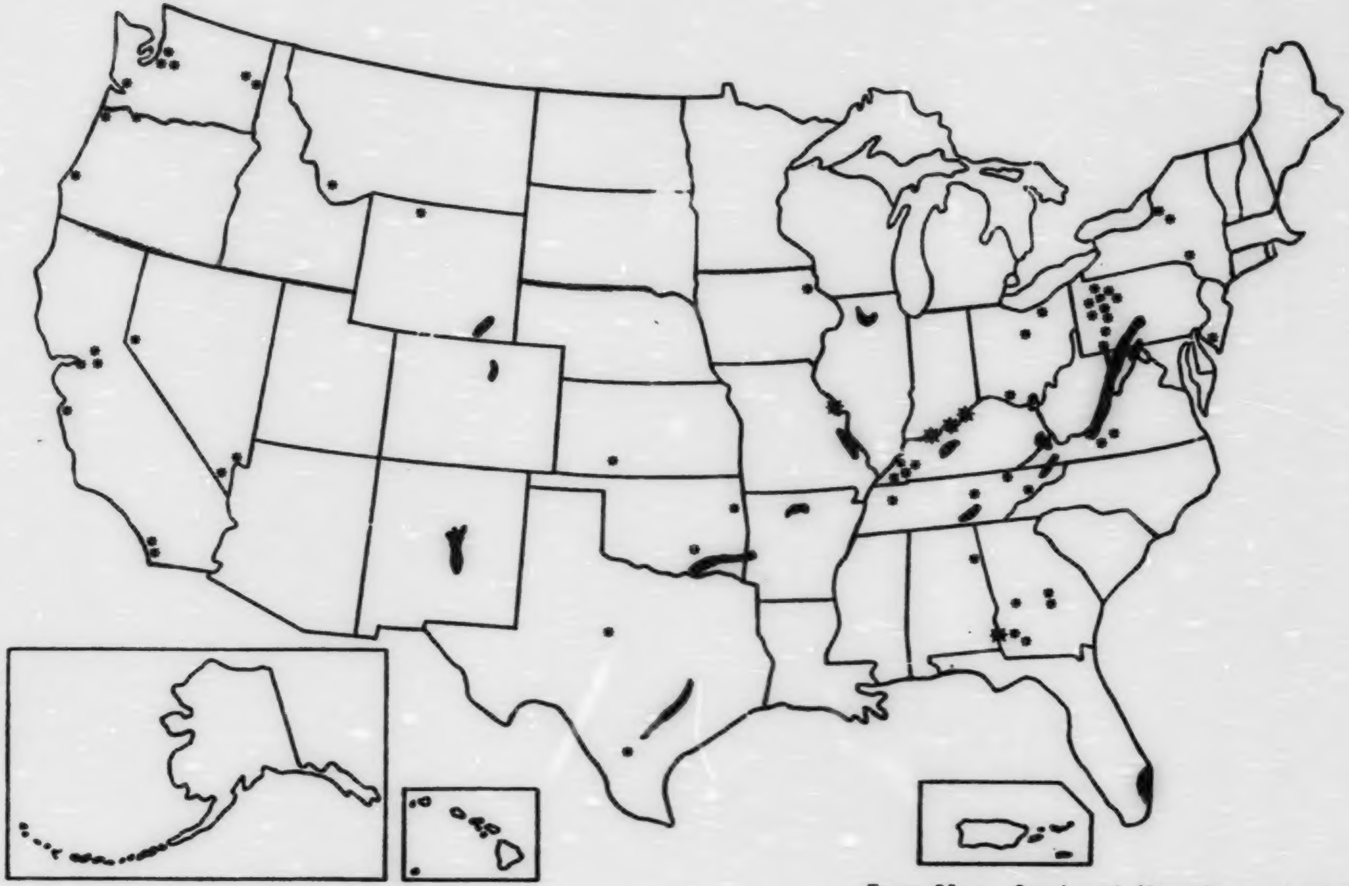
Blasting sand is a sound closely-sized quarts sand which, when propelled at high velocity by air, water, or controlled centrifugal force, is effective for such uses as cleaning metal castings, removing paint and rust, or renovating stone veneer. It is commonly referred to as sand blast sand. Chief sources of blasting sands are in Ohio, Illinois, Pennsylvania, West Virginia, New Jersey, California, Wisconsin, South Carolina, Georgia, Florida, and Idaho.

Glass-grinding sand is clean, sound, fine to medium-grained silica sand, free from foreign material and properly sized for either rough grinding or semifinal grinding of plate glass. Raw materials suitable for processing into these commodities comprise deposits of clean, sound sand, sandstone, and quartzite. As this commodity will not stand high transportation charges, sources of this material near sheet and plate glass facilities are the first to be exploited.

Stone-sawing and rubbing sand is relatively pure, sound, well-sorted, coarse-grained, siliceous material free from flats and fines used for sawing and rough-grinding dimension stone. Neither textural nor quality specifications are rigorous on this type of material as long as it is high in free silica and no clay, mica, or soft rock fragments are present. Chert tailings, locally known as chats in certain mining districts, are used successfully in regions close to the source of such materials. River terrace sand, and glacial moraine materials which have been washed and screened to remove oversize and fines, are often employed. Several important marble and granite producing districts are quite isolated from sources of clean silica sand and are forced to adapt to less efficient sawing and grinding materials in order to eliminate the high cost of long freight hauls.

Glass-melting and chemical sands are quartz sands of such high purity that they are essentially monomineralic; permissible trace impurities are variable according to use; grain shape is not a critical factor, but size frequency distribution can vary only between narrow limits.

FIGURE 8
INDUSTRIAL SAND DEPOSITS



From Glass Sand and Abrasives chart-pg.184
The National Atlas of The USA
USGS-1970

Table 9
1972 Uses of Industrial Sand

Use	Quantity		Value	
	1000 kkg	1000 short tons	$/kkg	$/ton
Unground				
Glass	9821	10828	4.20	3.81
Molding	6822	7522	3.64	3.30
Grinding and polishing	238	262	3.08	2.79
Blast sand	972	1072	6.46	5.86
Fire or furnace	638	703	3.52	3.19
Engine (RR)	545	601	2.54	2.30
Filtration	212	234	5.53	5.02
Oil Hydrofrac	256	282	4.18	3.79
Other	3187	3514	3.73	3.38
Ground Sand	4092	4512	5.26	4.77
Total	26784	29530	4.20	3.81

Minerals Yearbook, 1972, U.S. Department of the Interior, Bureau of Mines

Appropriate source materials are more restricted than for any other industrial silica commodity group. Because the required products must be of superlative purity and consequently are the most difficult and expensive to prepare, they command higher prices and can be economically shipped greater distances than nearly any other class of special sand.

To qualify as a commodity in this field the product must be a chemically pure quartz sand essentially free of inclusions, coatings, stains, or detrital minerals. Delivery to the customer in this highly refined state must be guaranteed and continuing uniformity must be maintained. At the present time the principal supply of raw materials for these commodities comes from two geological formations. The Oriskany quartzite of Lower Devonian age occurs as steeply dipping beds in the Appalachian Highlands. Production, in order of importance, is centered in West Virginia, Pennsylvania, and Virginia. The St. Peter sandstone of Lower Ordovician age occurs as flatlying beds in the Interior Plains and Highlands and is exploited in Illinois, Missouri, and Arkansas.

Metallurgical pebble is clean graded silica in gravel sizes, low in iron and alumina, used chiefly as a component in the preparation of silicon alloys or as a flux in the preparation of elemental phosphorus. A quartzite or quartz gravel, to qualify as a silica raw material chemically, must meet rigorous specifications. Metallurgical gravel is no exception and in the production of silicon alloys, purity is paramount. Such alloys as calcium-silicon, ferrosilicon, silicon-chrome, silicon copper, silicomanganese, and silicon-titanium are the principal products prepared from this material. The better deposits of metallurgical grade pebble occur principally as conglomerate beds of Pennsylvanian age, and as gravelly remnants of old river terraces developed from late Tertiary to Recent times.

Significant producing areas are in the Sharon conglomerate member of the Pottsville formation in Ohio. Silica pebble from the Sewanee conglomerate is produced in Tennessee for alloy and flux use. Past production for metallurgical use has come from the Olean conglomerate member of the Pottsville formation in New York, and the Sharon conglomerate member of the Pottsville formation in Pennsylvania. Production from terrace gravels comes from North Carolina, Alabama, South Carolina, and Florida in roughly decreasing order of economic importance. Marginal deposits of coarse quartzose gaavel occur in Kentucky. Terrace deposits of vein quartz gravel in California have supplied excellent material for ferrosilicon use in the past.

Industrial silica used principally for its refractory properties in the steel and foundry business is of several types: (a) core sand; (b) furnace-bottom sand; (c) ganister mix; (d) naturally bonded molding sand; (e) processed molding sand; (f) refractory pebble; and (g) runner sand.

A foundry sand used in contact with molten metal must possess a high degree of refractoriness; that is, it must resist sintering which would lead to subsequent adhesion and penetration at the metal-sand interface. To be used successfully as a mold or a core into which or around which molten metal is cast, it also must be highly permeable. This allows escape of steam and gases generated by action of the hot metal upon binders and additives in the mold or core materials. Such a sand must have sufficient strength under compression, shear, and tension to retain its molded form not only in the green state at room temperature, but also after drying and baking, and later at the elevated temperatures induced by pouring. Finally, it must be durable and so resist deterioration and breakdown after repeated use.

Core sand is washed and graded silica sand low in clay substance and of a high permeability, suitable for coremaking in ferrous and nonferrous foundry practice.

Furnace bottom sand is unwashed and partially aggregated silica sand suitable for lining and patching open hearth and electric steel furnaces which utilize an acid process. The term fire sand is often employed but is gradually going out of use. As for core sands, source materials for this commodity are quartz sands and sandstones which occur within reasonable shipping distances of steelmaking centers. Chief production centers are in Illinois, Ohio, Michigan, West Virginia, Pennsylvania, and New Jersey.

Ganister mix is a self-bonding, ramming mixture composed of varying proportions of crushed quartzose rock or quartz pebble and plastic fire clay, suitable for lining, patching, or daubing hot metal vessels and certain types of furnaces. It is variously referred to as Semi-silica or Cupola daub.

As in molding sands, there are two broad classes of materials used for this purpose. One is a naturally-occuring mixture of quartz sand and refractory clay, and the other is a prepared mixture of quartz in pebble, granule, or sand sizes bonded by a clay to give it plasticity.

Commercial ganister mix occuring naturally is exploited in two areas in California and one in Illinois. The California material contains roughly 75 percent quartz sand and lies between the 50 and 200 mesh sieves; the remaining portion is a refractory clay.

The bulk of this commodity is produced in the East and Mid-West where the foundry and steel business is centered. A large volume is produced from pebbly phases of the Sharon conglomerate in Ohio. The Veria sandstone of Mississippian age is crushed and pelletized for this purpose in Ohio. In Pennsylvania it is prepared from the Chickies quartzite of Lower Cambrian age, although some comes from a pebbly phase of the Oriskany. In Massachusetts, a post-Carboniferous hydrothermal quartz is used and in Wisconsin, production comes from the Pre-Cambrian Baraboo quartzite.

Naturally bonded molding sand is crude silica sand containing sufficient indigenous clay to make it suitable for molding ferrous or non-ferrous castings. Natural molding sands are produced in New York, New Jersey, and Ohio. Coarse-grained naturally bonded molding sand with a high permeability suitable for steel castings is produced to some extent wherever the local demand exists. Large tonnages are mined from the Connoquenessing and Homewood sandstone members of the Pottsville formation in Pennsylvania; the St. Peter sandstone in Illinois, and the Dresbach sandstone of Upper Cambrian age in Wisconsin.

Processed molding sand is washed and graded quartz sand which, when combined with appropriate bonding agents in the foundry, is suitable for use for cores and molds in ferrous and nonferrous foundry practice. Source materials which account for the major tonnage of processed molding sand are primarily the St. Peter formation in Illinois and Missouri, the Oriskany quartzite in Pennsylvania and West Virginia, the basal Pottsville in Ohio and Pennsylvania, and the Tertiary sands in New Jersey.

Refractory pebble is clean graded silica in gravel sizes, low in iron and alumina, used as a raw material for superduty acid refractories.

With few exceptions, bedded conglomerate and terrace gravel furnish the bulk of the raw material. Silica pebble in the Sharon conglomerate in Ohio, and the Mansfield formation in Indiana, are utilized. Significant production comes from a coarse phase of the Oriskany in Pennsylvania as well as from deposits of Bryn Mawr gravel in Maryland. Potential resources of conglomerate and terrace gravel of present marginal quality occur in other areas of the United States.

Other quartzitic formations are currently utilized for superduty refractory work. Notable production comes from the Baraboo quartzite in Wisconsin, the Weisner quartzite in

Alabama, and from quartzite beds in the Oro Grande series of sediments in California.

Runner sand is a crude coarse-grained silica sand, moderately high in natural clay bond, used to line runners and dams on the casting floor of blast furnaces. Runner sand is also used in the casting of pig iron. The term Casthouse sand also is used in the steel industry.

Coal-washing sand is a washed and graded quartz sand of constant specific gravity used in a flotation process for cleaning anthracite and bituminous coal.

Filter media consist of washed and graded quartzose gravel and sand produced under close textural control, for removal of turbidity and bacteria from municipal and industrial water supply systems.

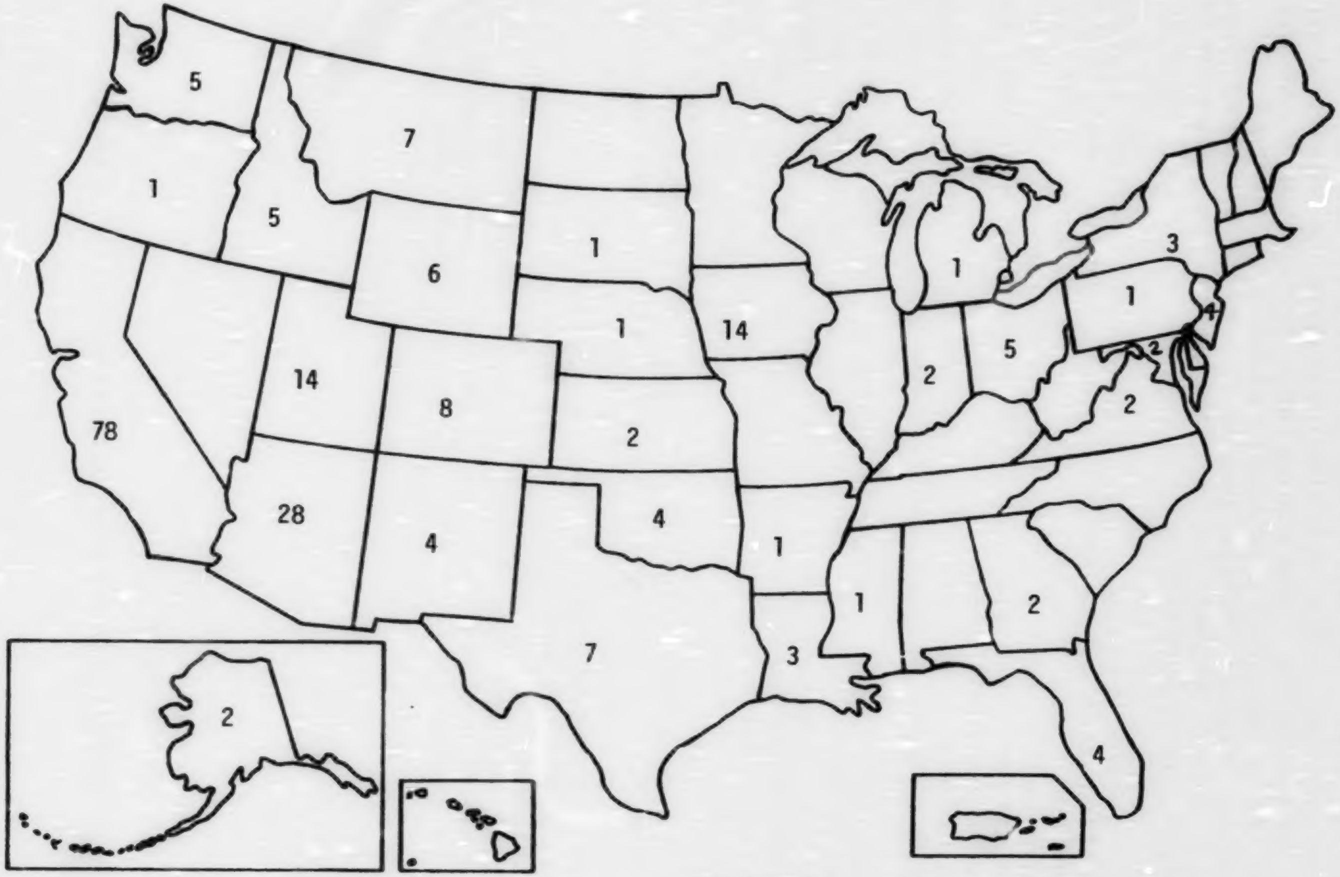
Hydraulic-fracturing sand is a sound, rounded, light-colored quartz sand free of aggregated particles and possessing high uniformity in specified size ranges which, when immersed in a suitable carrier and pumped under great pressure into a formation, increases fluid production by generating greater effective permeability. It is commonly referred to as Sandfrac sand in the trade.

GYPSUM (SIC 1492)

Gypsum is a hydrated calcium sulfate ($CaSO_4 \cdot 2H_2O$) generally found as a sedimentary bed associated with limestone, dolomite, shale or clay in strata deposited from early Paleozoic to Recent. Most deposits of gypsum and anhydrite ($CaSO_4$) are considered to be chemical precipitates formed from saturated marine waters. Deposits are found over thousands of square miles with thicknesses approaching 1800 feet - for example the Castle anhydrite of Texas and New Mexico. Field evidence indicates that most deposits were originally anhydrite which were subsequently subjected by surface hydration to gypsum.

Commercial gypsum deposits are found in many states of the United States with the leading producers being California, Iowa, Nevada, New York, Texas and Michigan with lesser amounts being produced in Colorado, and Oklahoma. Figure 9 shows the distribution of facility sizes. The ore is mined underground and from open pits with the latter being the more general method because of lower costs. In 1958, 44 of the 62 mining operations were open pits, while three of the remainder were combinations of open pit and underground mines. In quarrying operations, stripping of the overburden is usually accomplished with drag lines or with tractor equipment. Quarry drilling methods vary with local

FIGURE 9
GYPSUM OPERATIONS



Data From: Salines chart - p. 181
The National Atlas of USA
USGS - 1970

conditions, blasting is accomplished with low-speed, low density explosives. The fragmented ore is loaded with power shovels onto truck or rail transport to the processing facility. Generally, the primary crushing is done at the quarry site. Second-stage crushing is usually accomplished with gyratory units and final crushing is almost invariably by hammermills. The common unit for grinding raw gypsum is the air-swept roller process facility. Ground gypsum is usually termed "land plaster" in the industry because in this form, sacked or in bulk, it is also sold for agricultural purposes.

In recent years, a trend has started towards the beneficiation of low-grade gypsum deposits where strategic location has made this economically feasible. The heavy-media method has been introduced in two Ohio facilities; screening and air separation have been employed for improving purity in a limited number of other operations. The tonnage of gypsum thus beneficiated is still a small part of the total output.

Most mined and crushed gypsum is calcined to the hemi-hydrate stage by one of six different methods - kettles, rotary, calciner, hollow-flight screw conveyers, impact grinding and calcining mills, autoclaves, and beehive ovens. The calcined gypsum is used for various types of plasters, board and block, preformed gypsum tile, partition tile, and roof plank. By far the largest use of calcined gypsum (stucco) takes place in the manufacture of board products. Gypsum board is a sandwich of gypsum between two layers of specially prepared paper. It is manufactured in large machines by mixing the prepared stucco with water, foam and other ingredients and then poured upon a moving, continuous sheet of special heavy paper. Under "master rolls" the board is formed with the bottom paper receiving the wet slurry and another continually moving sheet of paper being placed on top, compacted, cut, and dried.

ASPHALTIC MINERALS

The bitumens are defined as mixtures of hydrocarbons of natural or pyrogenous origin or combinations of both, frequently accompanied by their derivatives, which may be gaseous, liquid, semisolid or solid and which are completely soluble in carbon disulfide. Oil shale and like materials which are mined for their energy content are not covered by this subcategory.

The principal bituminous materials of commercial interest are:

(1) Native asphalts, solid or semisolid, associated with mineral matter such as Trinidad Lake asphalt. Selenitza, Boeton and Iraq asphalts.

(2) Native Asphaltites, such as gilsonite, grahamite and glance pitch, conspicuous by their hardness, brittleness and comparatively high softening point.

(3) Asphaltic bitumens obtained from non-asphaltic and asphaltic crude petroleum by distillation, blowing with air and the cracking of residual oils.

(4) Asphaltic pyrobitumens of which wurtzilite and elaterite are of chief interest industrially as they depolymerize upon heating, becoming fusible and soluble in contrast to their original properties in these respects.

(5) Mineral waxes, such as ozokerite, characterized by their high crystallizable paraffine content.

There are several large deposits of bituminous sand, sandstone and limestone in various parts of the world but those of most commercial importance are located in the United States and Europe.

Commercial deposits of bituminous limestone or sandstone in the United States are found in Texas, Oklahoma, Louisiana, Utah, Arkansas, California, and Alabama. The bitumen content in these tends to run from 4 to 14 percent. Some of the sandstone in California has a higher content, about 15 percent, and a deposit in Oklahoma contains as high as 18 percent. The Uvalde County, Texas deposit is a conglomerate containing 10 to 20 percent of hard bitumen in limestone which must be mixed with a softer petroleum bitumen and an aggregate to produce a satisfactory paving mixture. Commercially, rock asphalt in this country is used almost exclusively for the paving of streets and highways.

Rock asphalt is mined from open quarries by blasting and is reduced to fines in a series of crushers and then pulverized in roller mills to the size of sand grains varying from 200 mesh to 1/4 inch in size.

Gilsonite, originally known as uintaite is found in the Uintah basin in Utah and Colorado. Gilsonite is a hard, brittle, native bitumen of variable but high softening point. It occurs in almost vertical fissures in rock varying in composition from sandstone to shale. The veins vary in width from 0.025 to 6.7 meters (1 in to 22 ft) and in length from a few kilometers to as much as 48 km (30 mi). The depth varies from a few meters to over 460 m (1500 ft).

Mining difficulties, such as the creation of a very fine dust which in recent years resulted in two or three serious explosions, and the finding of new uses for gilsonite necessitated one company to supplement the conventional pick-and-shovel method by the hydraulic system. However, on some properties the mining is still done by hand labor, compressed air picks, etc.

Grahamite occurs in many localities in the United States and in various countries throughout the world but never in large amounts. The original deposit was discovered in West Virginia but has long been exhausted. Deposits in Oklahoma were exploited to a great extent for years but little is now mined in commercial quantities.

The material differs from gilsonite and glance pitch having a much higher specific gravity and fixed carbon, and does not melt readily but intumesces on heating.

Glance pitch was first reported on the island of Barbados. The material is intermediate between gilsonite and grahamite. It has a specific gravity at 60°F of 1.09 to 1.15, a softening point (ring and ball) of 275° to 400°F and a fixed carbon of 20 to 30 percent.

Wurtzilite, sometimes referred to as elaterite, is one of the asphaltic pyrobitumens and is distinguished by its hardness and infusibility. It is found in Uintah County, Utah, in vertical veins varying from 2.5 cm to 63.5 cm (1 in to 25 in) in width and from a few hundred meters to 4.8 km (3 miles) in length. It is used in the manufacture of paints, varnishes, as an extender in hard rubber compounds, and various weatherproofing and insulating compounds.

Ozokerite is a solid waxlike bitumen the principal supply of which is found in the Carpathian mountains in Galicia. A small amount of it is also found in Rumania, Russia and the state of Utah. The hydrocarbons of which it is composed are solids, resembling paraffin scale and resulted from evaporation and decomposition of paraffinaceous petroleum. It occurs in either a pure state or it may be mixed with sandstone or other mineral matter. The material is mined by hand and selected to separate any material containing extraneous matter. Ozokerite when refined by heating to about 182°C (360°F), treated with sulfuric acid, washed with alkali and filtered through fuller's earth is called "ceresine."

ASBESTOS (SIC 1499)

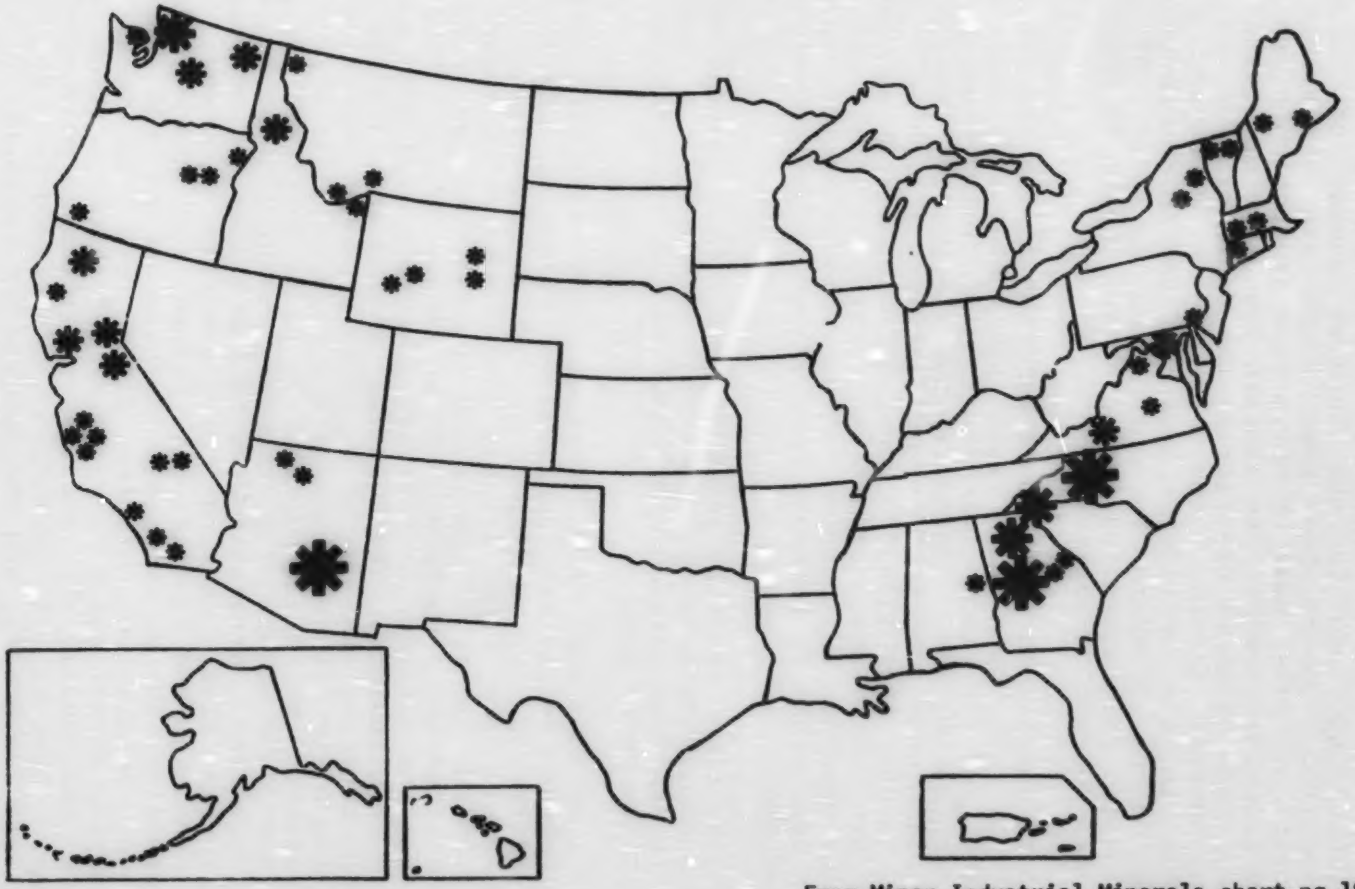
Asbestos is a broad term that is applied to a number of fibrous mineral silicates which are incombustible and which, by suitable mechanical processing, can be separated into fibers of various lengths and thicknesses. There are generally six varieties of asbestos that are recognized: the finely fibrous form of serpentine known as chrysotile and five members of the amphibole group, i.e., amosite, anthophyllite, crocidolite, tremolite, and actinolite. Chrysotile, which presently constitutes 93 percent of current world production, has the empirical formula $3MgO.2SiO_2.2H_2O$ and in the largest number of cases is derived from deposits whose host rocks are ultrabasic in composition. The bulk of chrysotile production comes from three principal areas: the Eastern Townships of Quebec in Canada, the Bajenova District in the Urals of USSR and from south central Africa. The ore-body of greatest known content in the United States is found in the serpentine formation of Northern Vermont which is part of the Appalachian belt extending into Quebec. Figure 10 shows the domestic asbestos deposits.

In North America the methods of asbestos mining are (1) open quarries, (2) open pits with glory holes, (3) shrinkage stoping, and (4) block caving; the tendency is toward more underground mining. In quarrying, the present trend is to work high benches up to 46 meters (150 feet) high and blast down 91,000 kkg (100,000 tons) or more of rock at a shot. An interesting feature of asbestos mining is that no wood may be used for any purpose unless it is protected, because it is impossible to separate wood fiber from asbestos in processing.

Since the fiber recovery averages only 5 to 6 percent of the rock mined, very large tonnages must be handled - a capacity of 910 kkg/day (1,000 tons/day) is about the minimum for profitable operation.

Milling methods used at the various mills vary in detail, but they are nearly all identical in principle. The objects of processing are to recover as much of the original fiber as possible, free from dirt and adhering rock; to expand and fluff up the fiber; to handle the ore as gently as possible to minimize the reduction in fiber length by attrition; and to grade the fibers into different length groups best suited to use requirements. The general method in use is (1) coarse crushing in jaw or gyratory crushers, sometimes in two stages, to 3.8 to 5.1 cm (1-1/2 to 2 in); (2) drying to 1 percent or less moisture, in rotary or vertical inclined-plane driers; (3) secondary crushing in short head cone crushers, gyratories, or hammer mills; (4) screening, usually in flat shaking or gyratory screens; (5) fine-crushing and fiberizing in stages, each stage followed by screening, during which air suction above the screens effects separation of the fiber from the rock; (6) collection of the fiber in cyclone separators, which also remove the dust; (7) grading of fibers in punched-plate trommel screens; (8) blending of products to make specification grades; and (9) bagging for shipment.

FIGURE 10.
ASBESTOS DEPOSITS



From Minor Industrial Minerals chart-pg.184
The National Atlas of The USA
USGS-1970

Fiberizing or opening up the bundles of fiber (step 5) is done in a special type of beater or impact process facility designed to free the fiber from the rock and fluff up the fiber without reduction in fiber length.

The screening operations are perhaps the most critical. The air in the exhaust hoods over each screen must be so adjusted that only the properly fiberized material will be lifted, leaving the rock and unopened fiber bundles for further fiberizing. The air system uses 20 to 25 percent of the total power consumed in a process facility.

WOLLASTONITE (SIC 1499)

Wollastonite is a naturally occurring, fibrous calcium silicate, $CaSiO_3$, which is found in metamorphic rocks in New York and California, as well as several foreign locations. In the U.S. the mineral is mined only in New York.

The material is useful as a ceramic raw material, as filler for plastics and asphalt products, as filler and extender for paints, and in welding rod coatings. Due to its fibrous, non-combustible nature, wollastonite is also being considered as a possible substitute for asbestos in a number of product situations in which asbestos is objectionable.

Wollastonite ore is mined by underground room and pillar methods and trucked to the processing facility. The ore is crushed in three stages, screened, dried, purified of garnet and other ferro-magnesium impurities via high-intensity magnetic separation and then ground to the desired product size.

LIGHT WEIGHT AGGREGATE MINERALS (SIC 1499)

PERLITE

Perlite is a natural glassy rhyolitic rock, essentially a metastable amorphous aluminum silicate, with an abundance of spherical or convolute cracks which cause it to break into small pearl-like masses usually less than a centimeter in diameter, formed by the rapid cooling of acidic lavas.

Since natural geological processes tend to work towards devitrification by progressive recrystallization and loss of water, most useful deposits of vitrified lava will be in recent lava flows of Tertiary or Quarternary age. Thus, most of the significant deposits of perlite in the United States are found in the Western states where active volcanism was recent enough that the perlite deposits are preserved. At the present time, the most important commercial deposit is in New Mexico.

Mining operations are open pit in locations chosen so that little overburden removal is required and where topographic factors are favorable for drainage and haulage of the crude ore. The ore is mined by loosening the perlite with a ripper to be picked up with a pan scraper. In some cases fragmentation is accomplished by blasting followed by a power shovel loading.

Milling proceeds by crushing in a jaw crusher and secondary roll crusher with the normal screening operations. The sized ore, after removal of fines which constitute roughly 25 percent of the process facility feed, is dried in a rotary kiln to a residual moisture content below 1 percent, and sent to storage for subsequent shipment to final processors.

The commercial uses of perlite are all predicted on the properties of expanded perlite. The glassy nature of the natural material, coupled with the inclusion of considerable moisture, when rapidly heated to 850-1100°C, results in the rapid evolution of steam within the softened glass, causing an explosive expansion of the individual fragments and producing a frothy mass having 15 to 20 times the bulk of original material. In commercial parlance, the term perlite is applied to both the crude ore and the expanded product. Approximately 70 percent of consumption is as an aggregate for plaster, concrete and for prefabricated insulating board wherein the perlite inclusion increases the fireproof rating of aggregate plaster as well as yielding a significant reduction in weight. The fact that perlite is relatively chemically inert and relatively incompressible along with the large surface area to volume ratios, makes it useful as an important filter-aid material in the treatment of industrial water and in the beverage, food and pharmaceutical processing industry.

The environmental problems associated with the mining and processing of perlite are almost entirely associated with the excessive amount of fines.

PUMICE

Pumice is a rhyolitic (the volcanic equivalent of a granite) glassy rock of igneous origin in which expanded gas bubbles have distended the magma to form a highly vesicular material. Pumicite has the same origin, chemical composition and glassy structure as pumice but during formation the pumicite was blown into small particles, hence the distinction is largely one of particle size in that pumicite has a particle size of less than 4 mm in diameter. Commercial usage has resulted in the generic term pumice being applied to all of the various rocks of volcanic ash origin.

The chemical composition of pumice varies from 72 percent silica, 14 percent alumina and 4 percent combined calcium, magnesium and iron oxides for the most acidic types to approximately 45 percent silica, 16 percent alumina, and 30 percent combined calcium, magnesium, and iron oxides for the most basic types.

The distribution of pumice is world wide, but due to metamorphism only those areas of relatively recent volcanism yield pumice deposits of commercial importance. One great belt of significant deposits borders the Pacific Ocean; the other trends generally from the Mediterranean Sea to the Himalayas and thence to the East Indies where it intersects the first belt. The largest producers within the United States are found in California and Idaho.

Mining operations are currently by open pit methods with the overburden removed by standard earth moving equipment. Since most commercial deposits of pumice are unconsolidated, bulldozers, pan scrapers, draglines or power shovels can be used without prior fragmentation.

When the mined pumice is used for railroad ballast or road construction, processing required consist of simple crushing and screening. Preparation for aggregate usually follows a similar procedure but with somewhat more involved sizing to produce a product conforming to rigorous specifications. Occasionally, the ore requires drying in rotary dryers either before or after crushing. Pumice prepared for abrasive use requires additional grinding followed by sizing via screening or air classification.

VERMICULITE

Vermiculite is the generic name applied to a family of hydrated-ferro-magnesium-aluminum silicates which, in the natural state have a characteristic micaceous habit and which readily split into their laminaie which are soft, pliable, and inelastic. Vermiculite deposits are generally associated with ultrabasic igneous host rocks such as pyroxenite or serpentine from which the vermiculite seems to have been formed by hydrothermal activity. Biotite and phlogopite mica, which frequently occur with vermiculite, are considered to have a similar origin.

When heated rapidly, to temperatures of the order of 1050-1100°C, vermiculite exfoliates by expanding at right angles to the cleavage into long wormlike pieces with an increase in bulk of from 8 to 12 times. The term vermiculite is applied both to the unexpanded mineral and to the commercial expanded product.

The bulk of domestically mined vermiculite comes either from the extensive deposit at Libby, Montana or from the group of deposits near Enoree, South Carolina. Mining operations are by open pit with removal of alluvial overburden accomplished by tractor-driven scrapers. The ore can be dug directly by power shovel or dragline excavator. Dikes or barren host rock require fragmentation by drilling and blasting prior to removal.

Ore beneficiation is accomplished by wet processing operations using hammer mills, rod mills, rake classifiers, froth flotation, cyclones, and screens. Centrifuges and rotary driers are used to remove excess moisture following beneficiation.

Exfoliation is carried out in vertical furnaces wherein the crude, sized vermiculite is top fed and maintained at temperatures from 900-1100°C for 4 to 8 seconds. The expanded product is removed by suction fans and passed through a classifier system to collect the product and to remove excessive fines.

MICA (SIC 1499)

Mica is a group name for a number of complex hydrous potassium aluminum silicate minerals differing in chemical compositions and in physical properties but which are all characterized by excellent basal cleavage that facilitates splitting into thin, tough, flexible, elastic sheets. There are four principal types of mica named for the most common mineral in each type - muscovite, phlogopite, biotite and lepidolite with muscovite (potassium mica) being commercially the most important. Mica, for commercial convenience, is broken down into ten broad classifications; sheet mica which consists of relatively flat sheets occurring in natural books or runs, and flake and scrap mica which includes all other forms.

Muscovite sheet mica is recovered only from pegmatite deposits where books or runs of mica occur sporadically as crystals which are approximately tabular hexagons ranging from a few centimeters to several meters in maximum dimension. Mica generally occurs as flakes of small particle size in many rocks. In addition, the mica content of some schists and kaolins is sufficiently high to justify recovery as scrap mica.

Domestic mica mining has been confined mainly to pegmatites in a few well-defined areas of the country. The largest area extends from central Virginia southward through western North and South Carolina and east-central Alabama. A second area lies discontinuously in the New England States, where New Hampshire, Connecticut, and Maine each possess mica bearing pegmatites. A third region comprises districts in the Black Hills of South Dakota and in Colorado, Idaho, and New Mexico. Additional sources of flake mica have been made available through the development of technology to extract small particle mica from schists and other host rocks. Deposits containing such mica are available throughout the U.S.

Sheet mica mines are usually small-scale operations. Open pit mining is used when economically feasible, but many mica bearing pegmatites are mined by underground methods. During mining care must be taken to avoid drilling through good mica crystals. Only a few holes are shot at one time to avoid the destruction of the available mica sheet. Presently there is no significant quantity of sheet mica mined in the U.S. Larger scale quarrying methods are used to develop deposits for the extraction of small-particle-size mica and other co-product minerals.

Flake mica that is recovered from pegmatites, schist, or other rock is obtained by crushing and screening the host rock and additional beneficiation by flotation methods in order to remove mica and other co-product minerals. Then it is fed to an oil-fired rotary dryer. The dryer discharge goes to a screen from which the fines can go to waste or be saved for further recovery.

Raw material for ground mica is obtained from sheet mica processing operations, from crushing and processing of schists, or as a coproduct of kaolin or feldspar production. Buhr mills, rodmills, or high-speed hammer mills have been used for dry-grinding mica. The process facility is in a circuit with an air separator which returns any oversize material for additional grinding and which discharges the fines to a screening operation. The various sized fractions are bagged for marketing. The ground mica yield from beneficiated scrap runs 95 to 96 percent.

"Micronized" mica is produced in a special type of dry-grinding machine, called a Micronizer. This ultrafine material is produced in a disintegrator that has no moving parts but uses jets of high-pressure superheated steam or air to reduce the mica to micron sizes. This type of mica is produced in particle size ranges of 10 to 20 microns and 5 to 10 microns.

Wet-ground mica is produced in chaser-type mills to preserve the sheen or luster of the mica. This process facility consists of cylindrical steel tank that is lined with wooden blocks laid with the end grain up. Wooden rollers are generally used, which revolve at a slow rate of 15 to 30 revolutions per minute. Scrap goes to the mill, where water is added slowly to form a thick paste. When the bulk of the mica has been ground to the desired size, the charge is washed from the process facility into settling bins where gritty impurities sink. The ground mica overflows to a settling tank and is dewatered by centrifuging and steam drying. The final product is obtained by screening on enclosed multiple-deck vibrating screens, stored and then bagged for shipment.

The major environmental problem in processing flake mica is the disposal of overburden material and flotation tailings, and reconditioning of unused or abandoned mine sites. Mining generally occurs away from highly urbanized areas, and land use conflicts are minor problems.

SECTION IV

INDUSTRY CATEGORIZATION

INTRODUCTION

In the development of effluent limitations guidelines and recommended standards of performance for new sources in a particular industry, consideration should be given to whether the industry can be treated as a whole in the establishment of uniform and equitable guidelines for the entire industry or whether there are sufficient differences within the industry to justify its division into categories. For this segment of the mineral mining and processing industry, which includes fifteen mineral products, the following factors were considered as possible justifications for industry categorization and subcategorization:

1) manufacturing processes;

2) raw materials

3) pollutants in effluent waste waters;

4) product purity;

5) water use volume;

6) facility size;

7) facility age; and

8) facility location.

INDUSTRY CATEGORIZATION

The first categorization step was to segment the mineral mining and processing industry according to product use. Thus, this volume, Volume I, is "Mining of Minerals for the Construction Industry," Volume II is "Mining of Minerals for the Chemical and Fertilizer Industry," and, Volume III is "Mining of Clay, Ceramic, Refractory, and Miscellaneous Minerals." The reason for this is twofold. First the industries in each volume generally have the same waste water treatment problems. Secondly, this division results in development documents that are not so big that the reader may easily forget earlier points as he reads from section to section.

The first cut in subcategorization was made on a commodity basis. This was necessary because of the large number of commodities and in order to avoid insufficient study of any one area. Furthermore, the economics of each commodity differs and an individual assessment is necessary to insure that the economic impact is not a limiting factor in establishing effluent treatment technologies. Table 10 lists the nine commodities and the twenty-nine subcategories in this report.

FACTORS CONSIDERED

Manufacturing Processes

Each commodity can be further subcategorized into three very general classes - dry crushing and grinding, wet crushing and grinding (shaping), and crushing and beneficiation (including flotation, heavy media, et al). Each of these processes is described in detail in Section V of this report, including process flow diagrams pertinent to the specific facilities using the process.

Raw Materials

The raw materials used are principally ores which vary across this segment of the industry and also vary within a given deposit. Despite these variations, differencies in ore grades do not generally affect the ability to achieve the effluent limitations. In cases where it does, different processes are used and subcategorization is better applied by process type as described in the above paragraph.

TABLE 10

	Industry Categorization	
Commodity	SIC Code	Subcategory
Dimension stone	1411	No further subcategorization
Crushed stone	1422,1423, 1429,1499	Dry
		Wet
		Flotation
Construction sand and gravel	1442	Dry
		Wet
		Dredging, on-land processing
Industrial sand	1446	Dry
		Wet
		Flotation (acid and alkali)
		Flotation (HF)
Gypsum	1492	Dry
		Dry, wet scrubbers
		HMS
Asphaltic Minerals	1499	Bituminoius lime-stone
		Oil impregnated diatomite
		Gilsonite
Asbestos and Wollastonite	1499	Asbestos, Dry
		Asbestos, Wet
		Wollastonite
Lightweight Aggregates	1499	Perlite
		Pumice
		Vermiculite
Mica and Sericite	1499	Dry
		Wet
		Wet Beneficiation either no clay or general purpose clay by-product
		Wet Beneficiation cer.gr. by-product

Product Purity

The mineral extraction processes covered in this report yield products which vary in purity from what would be considered a chemical technical grade to an essentially analytical reagent quality. Product purity was not considered to be a viable criterion for categorization of the industry. Pure product manufacture usually generates more waste than the production of lower grades of material, and thus could be a basis for subcategorization. As is the case for variation of ore grade discussed under raw materials previously, pure products usually result from different beneficiation processes, and subcategorization is better applied there.

Facility Size

For this segment of the industry, information was obtained from more than 400 different mineral mining sites. Capacity varied from as little as 5 to 5,000 kkg/day. Setting standards based on pounds pollutant per ton production minimizes the differences in facility sizes. The economic impact on facility size will be addressed in another study.

Facility Age

The newest facility studied was less than a year old and the oldest was 150 years old. There is no correlation between facility age and the ability to treat process waste water to acceptable levels of pollutants. Also the equipment in the oldest facilities either operates on the same principle or is identical to equipment used in modern facilities. Therefore, facility age was not an acceptable criterion for categorization.

Facility Location

The locations of the more than 400 mineral mining and processing sites studied are in 45 states spread from coast to coast and north to south. Some facilities are located in arid regions of the country, allowing the use of evaporation ponds and surface disposal on the facility site. Other facilities are located near raw material mineral deposits which are highly localized in certain areas of the country.

In general the principal factor within facility location affecting effluent quantity or quality is the amount of precipitation and evaporation. Appropriate consideration of these factors was taken where applicable, most notably mine water discharge.

SECTION V

WATER USE AND WASTE CHARACTERIZATION

INTRODUCTION

This section discusses the specific water uses in the minerals for the construction industry segment of the mineral mining and processing industry, and the amounts of process waste materials contained in these waters. The process wastes are characterized as raw waste loads emanating from specific processes in the extraction of the materials involved in this study and are given either in terms of kg/kkg of product produced or ore processed. The specific water uses and amounts are given in terms of l/kkg of product produced or ore mined (gal/ton) for each of the facilities contacted in this study. The treatments used by the mining and processing facilities studied are specifically described and the amount and type of water borne waste effluent after treatment is characterized.

The verification sampling data measured at specific facilities for each subcategory is included in this report where industry data and data from other sources is lacking.

SPECIFIC WATER USES

Waste water originates in the mineral mining and processing industry from the following sources.

(1) Non-contact cooling water
(2) Process generated water - wash water
    transport water
    scrubber water
    process and product consumed water
    miscellaneous water
(3) Auxiliary processes water
(4) Storm and ground water - mine water
    storm runoff

Non-contact cooling water is defined as that cooling water which does not come into direct contact with any raw material, intermediate product, by-product or product used in or resulting from the process or any process water. Such water will be regulated by general limitations applicable to all industries.

Process generated waste water is defined as that water which, in the mineral processing operations such as crushing, washing, and benefication, comes into direct contact with any raw material, intermediate product, by-product or product used in or resulting from the process.

Auxiliary processes water is defined as that used for processes necessary for the manufacture of a product but not contacting the process materials, for example influent water treatment. Such water will be regulated by general limitations applicable to all industries.

The quantity of water usage for facilities in the minerals for the construction industry segment of the mineral mining and processing industry ranges from 0 to 2,640,000 l/day (0 to 656,000 gal/day). In general, the facilities using very large quantities of water use it for heavy media separation and flotation processes and, in some cases, wet scrubbing and non-contact cooling.

Non-Contact Cooling Water

The largest use of non-contact cooling water in this segment of the mineral mining industry is for the cooling of equipment, such as crusher bearings, dryers, pumps and air compressors.

Contact Cooling Water

Insignificant quantities of contact cooling water is used in this segment of the mineral mining industry. When used, it usually either evaporates immediately or remains with the product.

Wash Water

This water also comes under the heading of process water because it comes into direct contact with either the raw material, reactants or products. Examples of this type of water usage are ore washing to remove fines and washing of crushed stone, sand and gravel. Waste effluents can arise from these washing sources, due to the fact that the resultant solution or suspension may contain impurities or may be too dilute a solution to reuse or recover.

Transport Water

Water is widely used in the mineral mining industry to transport ore to and between various process steps. Water is used to move crude ore from mine to facility, from crushers to grinding mills and to transport tailings to final retention ponds. Transport water is process water.

Scrubber Water

Particularly in the dry processing of many of the minerals in this industry, wet scrubbers are used for air pollution control. These scrubbers are primarily used on dryers, grinding mills, screens, conveyors and packaging equipment. Scrubber water is process water.

Process and Product Consumed Water

Process water is primarily used in this industry during blunging, pug processing, wet screening, log washing, heavy media separation and flotation unit processes. The largest volume of water is used in the latter four processes. Product consumed water is often evaporated or shipped with the product as a slurry or wet filter cake.

Miscellaneous Water

These water uses vary widely among the facilities with general usage for floor washing and cleanup, safety showers and eye wash stations and sanitary uses. The resultant streams are either not contaminated or only slightly contaminated with wastes. The general practice is to discharge such streams without treatment or combine with process water prior to treatment.

Another miscellaneous water use in this industry involves the use of sprays to control dust at crushers, conveyor transfer points, discharge chutes and stockpiles. This water is usually low volume and is either evaporated or adsorbed on the ore. The water uses so described are process waters.

Auxiliary Processes Water

Auxiliary processes water include blowdowns from cooling towers, boilers and water treatment. The volume of water used for these purposes in this industry is minimal. However, when they are present, they usually are highly concentrated in waste materials.

Storm and Ground Water

Water will enter the mine area from three natural sources, direct precipitation, storm runoff and ground water intrusion. Water contacting the exposed ore or disturbed overburden will be contaminated. Storm water and runoff can also become contaminated at the processing site from storage piles, process equipment and dusts that are emitted during processing.

PROCESS WASTE CHARACTERIZATION

The mineral products are discussed in Standard Industrial Classification (SIC) Code numerical sequence in this section. For each mineral product the following information is given:

- -- a short description of the processes at the facilities studied and pertinent flow diagrams;
- -- raw waste load data per unit weight of product or raw material processed;
- -- water consumption data per unit weight of product or raw material processed;
- -- specific facility waste effluents found and the post-process treatments used to produce them.

DIMENSION STONE (SIC 1411)

Sixteen dimension stone quarries and/or processing facilities were inspected for the purpose of studying this industry. These companies employ almost 3,200 persons and process about 300,000 kkg/yr (330,000 tons/yr) of finished dimension stone products. Production of quarry stone was about 1,340,000 kkg (1,480,000 tons) in 1972.

Process Description

The quarrying of dimension stone can be accomplished using six primary techniques. Some can be used singly, most are used in various combinations. These techniques, their principal combinations, and their areas of use, are discussed as follows:

(1) Drilling, with or without broaching, dry or wet, simply results in circular holes in the stone. On occasion, shallow drilling of holes a few centimeters apart is the prelude to insertion of explosive charges, or to insertion of wedges, or wedges with two especially shaped iron strips ("plugs-and-feathers"). On other occasions, drilling of deeper holes, followed by removal of stone between holes (broaching) is the primary means of stone cutting. Drilling is either dry or wet with water serving to suppress dust, to wash away stone chips from the working zone, and to keep the drills cool and prolong the cutting edge. Drilling to some extent is necessary in virtually all dimension stone quarrying.

(2) Channel machines are simple, long, semi-automated, multiple-head chisels. They are electrically or steam powered (with the steam generating unit an integral part of each machine), and are primarily used on limestone along with other techniques. The machines are always used with water, primarily to remove stone chips which are formed by machine action.

(3) Wire sawing is another technique requiring the use of water. Generally, a slurry of hard sand or silicon carbide in water is used in connection with the saw. The use of wire saws is probably not justified in small quarries, as the initial setup is time consuming and costly. However, the use of wire saws permits decreased effort later at the saw facility, and will result in decreased loss of stone. Wire saws are used chiefly on granite and limestone.

(4) Low level explosives, particularly black powder, are used in the quarrying of slate, marble, and mica schist.

(5) Jet piercing is used primarily with granite in the dimension stone industry. This technique is based on the use of high velocity jet flames to cut channels. It involves combustion of oxygen and a fuel oil fed under pressure through a nozzle to attain jet flames of over 2600°C (5000°F). A stream of water joins the flame and the combined effect is spalling and disintegration of the rock into fragments which are blown out of the immediate zone.

(6) Splitting techniques of one sort or another seem to be used in the quarry on nearly all dimension stones. Splitting always requires initial spaced drilling of holes in the stone, usually along a straight line, and following the "rift" of the stone if it is well defined. Simple wedges, or "plugs-and-feathers" are inserted in the holes and a workman then forces splitting by driving in the wedges with a sledge hammer. This technique appears crude, but with a skilled workman good cuts can be made.

After a large block of stone is freed, it is either hoisted on to a truck which drives from the floor of the quarry to the facility, or the block is removed from the quarry by means of a derrick, and then loaded on a truck.

Most dimension stone processing facilities are located at or close to the quarry. On occasion, centrally located facilities serve two or more quarries (as facilities 3029, 3038, 3053, 3007, 3051). To a much lesser extent, one quarry can serve two or more processors (as at facilities

3304 and 3305). Also in a well defined, specialized producing area such as Barre, Vermont, two large quarriers, who are also stone processors, sell blocks and/or slabs to approximately 50 processors. However, the most common situation is that in which the processor has his own quarry. In this study, no situation was seen in which a quarry was operated without an accompanying processing facility.

In dimension stone processing, the first step is to saw the blocks into slabs. The initial sawing is accomplished using gang saws (large hack saws), wire saws, or occasionally, rotating diamond saws. All saw systems use considerable water, for cooling and particle removal, but this water is usually recycled. Generally, the saw facility is operated at the same physical location as the finishing facility, and without any conscious demarkation or separation, but in a few cases the saw facility is either at a separate location (facilities 3034 and 3051), is not associated with any finishing operations (facilities 3008, 3010 and 5600), or is separately housed and operated but at the same location (facilities 3007 and 3001).

After the initial sawing of blocks to slabs of predetermined thickeness, finishing operations are initiated. The finishing operations used on the stone are varied and are a function of the properties of the stone itself, or are equally affected by characteristics of the end product. For example, after sawing, slate is hand split without further processing if used for structural stone, but is hand split, trimmed, and punched if processed to shingles, and it is hand split and trimmed if processed to flagstone. Slate is rarely polished, as the rough effect of hand splitting is desirable. Mica schist and sandstone are generally only sawed, since they are used primarily for external structural stone. Limestone cannot be polished, but it can be shaped, sculptured and machined for a variety of functional and/or primarily decorative purposes. Granite and marble are also multi-purposed stones and can take a high polish. Thus polishing equipment and supplies, and water usage, are important considerations for these two large categories of stone. Dolomitic limestone can be polished, but not to the same degree as granite or marble. Generally most of this stone is used primarily for internal or external structural pieces, veneer, sill stone, and rubble stone. A schematic flow sheet for dimension stone quarrying and processing is given in Figure 11.

Raw Waste Loads

Extremely large quantities of stone are quarried in the dimension stone industry, and yields of good quality stone are quite low and variable, from 15 percent to 65 percent,

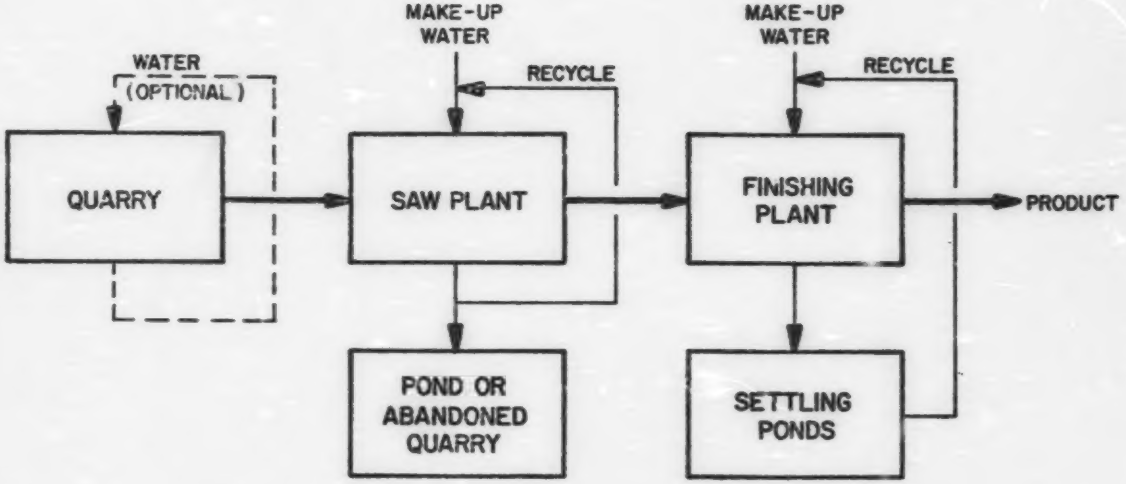


FIGURE 11
DIMENSION STONE MINING AND PROCESSING

with 0.5 to 5.7 kkg of waste stone per kkg of product. The lowest yields are characteristic of the stones which are generally highly polished and therefore require the most perfection (granite and marble). Low yields (18 percent) also occur in slate due to large quantities of extraneous rock. Most of the yield losses occur at the quarry but some unavoidable yield losses also occur in the saw facilities and finishing facilities. The table below lists some dimension stone quarry and facility yields.

Stone Type	Facility	Yield	Loss kkg/kkg Product
Slate	3053	18%	4.56
Dolomitic limestone	3040	65%	0.54
Limestone	3010	35%	1.86
	3007	50%	1.00
Marble	3051	25%	3.00
Granite	3001	15%	5.67
	3038	15-40%*	5.67-1.50

* Many quarries of differing stones and locations.

Untreated aqueous effluents can occur in the quarry and at the saw and finishing facilities.

Some quarries use no water: mica schist, dolomitic limestone, slate and sandstone, (facilities 5600, 3017, 3018, 3053, 3039, 3040), plus some marble, travertine marble, and granite (facilities 3051, 3034, 3001, 3029). Ground or rain waters do accumulate in these quarries but rarely cause severe problems. Most limestone and some granite quarries do use water for sawing or channel cutting, (facilities 3038, 3304, 3305, 3306, 3007, 3008, 3009, 3010) therefore, ground and rain water is retained, and other sources of water may also be tapped for makeup. This water is continuously recycled into the quarry sump and is rarely discharged.

All saw facilities use water and the general practice is to recycle after settling most of the suspended solids. The quality of untreated effluent from saw facilities can be significant. However, no data is available of the raw waste load (dissolved and suspended solids) of these effluents. The same situation is true of untreated effluents from finishing facilities. In many cases, the saw facilities and the finishing facilities are under the same roof, in which case the water effluents are combined.

Water Use

In the quarrying of dimension stone, water is used in quantity wherever two specific quarrying methods are used. The methods are wire sawing and channel machining (facility-quarries 3038, 3007, 3008, 3009, 3010, 3304, 3305, 3306). In all cases, rain and ground water are used, without pretreatment, as well as water from any other convenient source (creek, city water, abandoned quarry, etc.). In no case has the quantity of water used been determined. Water is also used in wet drilling, but this quantity is small and not measured.

In the saw and finishing facilities, water is used with the gang saws, wire saws, diamond saws, polishing mills, grinders, and in final washing. The greatest quantity of water is used in sawing, whether it is for initial sawing in the saw facility or in connection with operations in the finishing facility.

In Table 11, water and effluent data are presented for dimension stone facilities having reliable data available. Combined saw facility and finishing facility raw water effluents vary from 4,340 to 43,400 l/kkg of product (1,040 to 10,400 gal/ton). Water usage varies due to varying stone processes, water availability, and facility attitudes on water usage.

The quality of water used in dimension stone processing appears to be of little concern. For the most part, river, creek, well, abandoned quarry, or lake water is used without prior treatment. Occasionally pretreatment in the form of prior elementary screening or filtration is performed (facilities 3018, 3051), and in only two instances is city water used (facility 3007, 3029) as part of the makeup water.

Waste Water Treatment

In an industry where process feed water is largely obtained from any convenient source, and used with virtually no pretreatment, it would be unexpected to find a high degree of sophistication in the treatment of waste water. Such is the case in most of the dimension stone industry.

In no known case is quarry water given any treatment prior to its discharge to a convenient stream, field, abandoned quarry or settling pond. This type of pumpout is quite infrequent, the water contains only small quantities of suspended solids (usually <25 mg/l) and no known toxic pollutants.

TABLE 11
Dimension Stone Water Use

Stone and Plant	Makeup Water l/kkg of stone processed (gal/ton)	Water Use, l/kkg of stone processed (gal/1000 lb)		Combined
		Saw Plant	Finish Plant	
Mica Schist				
5600	20 (5)	4,460	none	4,460
Slate				
3053	450 (110)	unknown	unknown	4,550
Dolomitic Limestone				
3039	1,250 (300)	unknown	unknown	unknown
3040	13,000 (3100)	unknown	unknown	13,000
Limestone				
3007	540 (130)	16,600	1,600	18,200
3009	unknown	unknown	unknown	6,030
3010*	unknown	9,800		9,800
Granite				
3001	unknown	7,350	7,360	14,700
3029	840 (200)	unknown	unknown	3,900
3038	1,600 (390)	unknown	unknown	43,400
Marble				
3051	100,000 (24,000)	100,000	unknown	unknown
3304	590 (140)	unknown	unknown	5,940
3305	unknown	unknown	unknown	39,800**
3306	1,300 (300)	unknown	unknown	6,500

* No finishing plant

** Primarily a saw plant which ships slabs to 3304 for finishing.

In dimension stone processing facilities, water is generally used with no recycle or with 70-100 percent recycle. Facility effluents may be discharged with no treatment whatsoever (facilities 3018, 3051), discharged after settling in ponds or quarries (facilities 5600, 3053, 3039, 3040, 3007, 3008, 3009, 3001, 3029, 3034, 3304, 3305), discharged or recycled after chemical treatment and settling (facilities 3038, 3306), or there may be no effluent whatsoever (facilities 3017, 3010) due to 100 percent recycle. This data is summarized in the following table.

Stone	Facility	Waste Water Treatment
Mica Schist	5600	settling
Slate	3017	100% recycle
	3018	none
	3053	settling
Dolomitic Limestone	3039	settling
	3040	settling
Limestone	3007	settling
	3008	settling, 100% recycle
	3009	settling
	3010	settling, 100% recycle
Granite	3001	settling
	3029	settling
	3038	flocculants, settling, 100% recycle
	3002	settling
	3003	settling
Marble	3034	settling
	3051	none
	3304	settling
	3305	settling
	3306	settling, polymer, alum

At facility 3038 there is chemical treatment of facility waste effluents, solids separation via a raked tank with filtration of tank underflow, plus total recycle of tank overflow. This practice is necessary since the facility hydraulic load would otherwise overwhelm the small adjacent river. Furthermore, the facility has a proprietary process for separating silicon carbide particles from other solids in order to resell this valuable by-product. Since granite facilities are the only users of silicon carbide, non-granite processors could not obtain any cost benefits from this practice.

Effluents and Disposal

Disposition of quarry and facility waste stone is more a function of state requirements than of any other factor. Thus, waste stone and settling pond solids are conscientiously used to refill and reclaim quarries where the state has strict reclamation laws. Corporate policy regarding disposition of solid wastes is the second most important factor, and type and yield of stone is the least important factor. Thus, where both state and corporate policy are lenient, solid wastes are accumulated in large piles near the quarry (facilities 3017, 3053, and to some extent 3051).

In addition to refilling abandoned quarries, some facilities make real efforts to convert waste stone to usable rubble stone (facilities 3034, 3040), crushed stone (facilities 3051, 3038, 3018), or sell as rip rap (facilities 3051, 3039). Successful efforts to convert low grade stone to low priced products are seen only in the marble, granite, and dolomitic limestone industries. The only estimate that can be made of solid wastes, regardless of disposition, is that which is based on data in the last column of a preceding table of stone losses, which shows the loss of dimension stone as kg/kkg product.

On the average, dimension stone facilities are much more careful in their handling of water effluents than they are for solid wastes. The most important factors are state and federal agencies which impose or are likely to impose strict regulations. The single important water effluent parameter for this industry is suspended solids.

Some quarries use no water (generally mica schist, dolomitic limestone, slate, sandstone). Water use is associated with channel machines and wire saws (mining methods), and thus it is seen in limestone quarrying (facilities 3007, 3008, 3009 and 3010), and to some extent in granite (facility 3038), and marble (facilities 3304, 3305, 3306).

Where water is used in quarrying, there is 100 percent recycle. Pit pumpout does occur as a seasonal factor at some locations, but suspended solids have generally been found to be less than 25 mg/l. If there is a problem or a border-line situation with respect to suspended solids, it can be attributed more to stone type than to any other factor. For example, granite quarry pumpout at facility 3001 is 25 mg/l TSS. However, limestone, marble, and dolomitic limestone quarry water is generally very clear and much lower in suspended solids.

At no facility where wet quarrying methods are used is the water flow measured. Likewise, pit pumpout which is generally infrequent, is rarely measured. A few existing state permits for pit pumpout are specified in terms of total pumpout for given periods of time, as well as allowable levels of pollutants (primarily suspended solids, pH, and turbidity).

Very little quantitative data is available on the quality or quantity of dimension stone processing facility treated effluents. The common method of treatment simply involves the use of settling ponds. In some cases, the settling ponds lose so much water by seepage that there is no overflow. In other cases, the settling pond effluent flow rate does not match the raw waste flow rate due to increases in volume from rainfall and runoff and decreases from seepage, evaporation, and undetermined degrees of water recycle to the processing facilities.

Several analyses of treated effluents available are as follows:

Facility 3007	7.8 pH
	7.1 mg/l TSS (range 0-24.5)
Facility 3304	<10 JTU
Facility 3305	<100 mg/l total solids
	<5 mg/l TSS
	<1 BOD
Facility 3306	<1 JTU
Facility 3002	600 mg/l TSS
Facility 3003	34 mg/l TSS
Facility 3001	Water including runoff from 2 quarries
	1 mg/l TSS
	4 mg/l TSS
	Finishing Facility 37 mg/l TSS
Facility 5600	Quarry - 7 mg/l TSS
Facility 3051	Quarry - 7 mg/l TSS
	Facility 1658 mg/l TSS
	Second Facility 4008 mg/l TSS

CRUSHED STONE (SIC 1422, 1423, 1429)

There are more than 4,600 quarries producing crushed stone in the United States, in every state except Delaware. The types of stone mined and crushed include: limestone and dolomite (73 percent of the total tonnage); granite; trap rock; marble; shell; calcareous marl; sandstone, quartz, and quartzite; slate; and other stone. Pennsylvania leads the nation in yearly output which combined with the outputs of Florida, Illinois, Ohio, and Texas account for approximately one-third of the total U.S. production.

Facilities smaller than 22,700 kkg/yr (25,000 tons/yr) account for less than 2 percent of the total production. The principal use for crushed stone of all kinds is as an aggregate in the construction and paving industries. The crushed stone industry is the largest non-fuel, non-metallic mineral industry in the United States from the standpoint of total value of production and is second only to sand and gravel in volume production.

Three basic methods of extraction are practiced: (1) removal of raw material from an open face quarry; (2) removal of raw material from an underground mine (approximately 5 percent of total crushed stone production); and (3) shell dredging, mainly from coastal waterways (approximately 1 percent of total crushed stone production). Once the raw material is extracted, methods of processing are similar, consisting of crushing, screening, washing, sizing, and stockpiling. Approximately 0.2 percent of total crushed stone production employ flotation techniques to obtain a calcite ($CaCO_3$) product.

Based on 189 facility contacts (approximately 4 percent of the total facilities), the industry was divided into the following subcategories:

(1) Dry process (52 facilities contacted)
(2) Wet process (130 facilities contacted)
(3) Flotation process (3 facilities contacted)
(4) Shell dredging (4 facilities contacted)

These facilities are located in 38 states in all areas of the nation representing various levels of yearly production and facility age. Production figures range from 36,000 - 1,180,000 kkg/yr (40,000-1,300,000 tons/yr) and facility ages vary from less than one year to over 150 years old.

DRY PROCESS

Process Description

Most crushed stone is mined from quarries. After removal of the overburden, drilling and blasting techniques are employed to loosen the raw material. The resulting quarry is characterized by steep, almost vertical walls, and may be several hundred meters deep. Excavation is normally done on a number of horizontal levels, termed benches, located at various depths. In most cases, front-end loaders and/or power shovels are utilized to load the raw material into trucks which in turn transport it to the processing facility. In some cases, however, the raw material is moved to the facility by a belt conveyor system perhaps preceded by a primary crusher. Another variation is the use of portable processing facilities which can be situated near the blasting site, on one of the quarry benches or on the floor of the quarry. In this situation, the finished product is trucked from the quarry to the stockpile area. Specific methods vary with the nature and location of the deposit.

No distinction is made between permanent facilities and portable facilities since the individual operations therein are basically identical. At the processing facility, the raw material passes through screening and crushing operations prior to the final sizing and stockpiling. Customer demands for various product grades determines the number and position of the screens and crushers. Figure 12 is a dry process flow diagram.

Raw Wastes

The raw wastes from the process consist of oversized or undersized crushed stone and is usually disposed of in pits. The amounts of these solid wastes are variable, depending on the specific grades of material being processed. It is difficult to determine an average value of raw waste per metric ton of product processed, since the industry does not produce a great deal of solid waste.

Water Use

No process water is used in the crushing and screening of dry process crushed stone. Many operators dewater their quarries because of ground water, rain, or surface runoff. Approximately half of the quarries studied dewater their quarries either on an intermittent or continual basis.

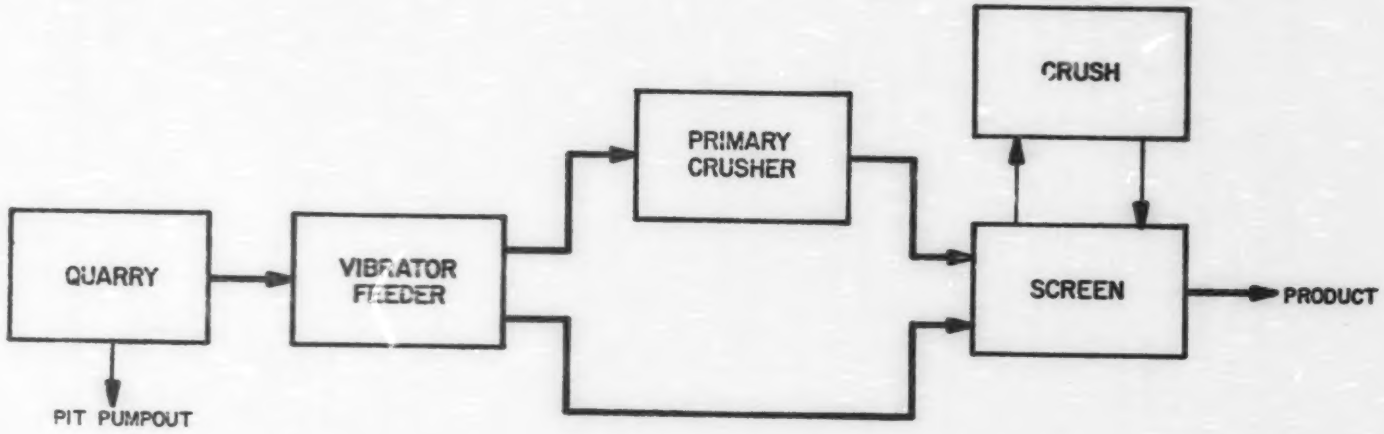


FIGURE 12
CRUSHED STONE MINING AND PROCESSING
(DRY)

Incidental water uses include non-contact cooling water for cooling crusher bearings and water used for dust suppression, which is adsorbed onto the product and does not result in a discharge.

	Incidental Water Use l/kkg of product (gal/ton)	
Facility	Non-contact cooling	Dust suppression
1044	40 (9.5)	None
1216	38 (9.2)	81 (20)
5660	None	6.0 (1.5)

Waste Water Treatment

Pit pumpout and non-contact cooling water are usually discharged without treatment. Some facilities, such as 1020, pump their quarry water through settling ponds prior to discharge. Other facilities such as 1216 and 1022 are able to recycle about one half of their non-contact cooling water.

Effluent and Disposal

Facilities in this subcategory are characterized by a waterborne effluent in the form of pit pumpout and some discharge non-contact cooling water.

CRUSHED STONE, WET PROCESS

Process Description

Excavation and transportation of crushed stone for wet processing use methods identical to those for dry processing. Wet processing is the same as dry processing with the exception that water is added to the system for washing the stone. This is normally done by adding spray bars to the final screening operation after crushing. Figure 13 is a process flow diagram for wet processing crushed stone. In many cases, not all of the product is washed, and a separate washing facility or tower is incorporated which receives all of the material to be washed. This separate system will normally only include a set of screens for sizing which are equipped with spray bars. In the portable processing facility, a portable wash facility can also be incorporated to satisfy the demands for a washed material. At facility 5662, the finished product from the dry facility is fed into a separate unit consisting of a logwasher and screens equipped with spray bars.

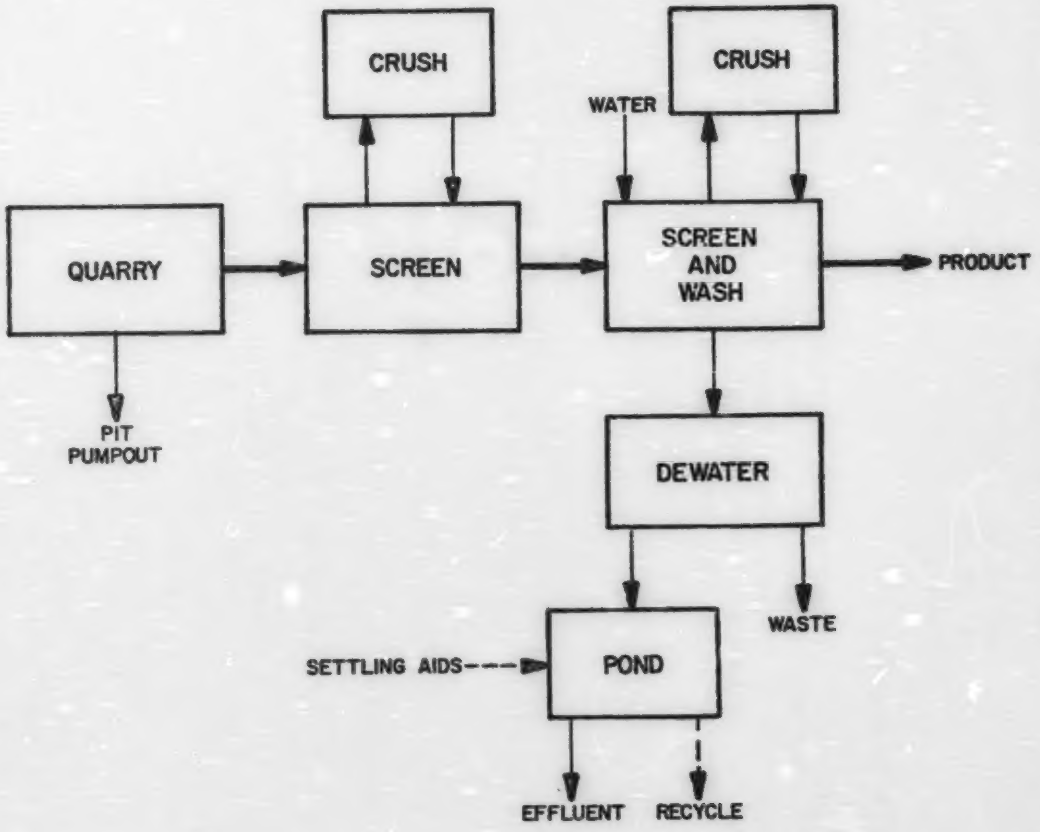


FIGURE 13
CRUSHED STONE MINING AND PROCESSING
(WET)

Raw Waste Loads

The raw waste loads of wet processing facilities are similar to those from dry processing facilities. The quantity of raw waste varies as shown by the tabulation as follows:

Facility	Raw Waste Load, kg/kkg of product (lb/1000 lb)
1001	40
1002	50
1003	40
1004	150
1021	80
1023	20
1039	20
1212	270
1213	30
1215	10
1221	130
1974	22
5640	10
5664	180

Water Use

Incidental water is also used for non-contact cooling and/or dust suppression. Use varies widely as shown below:

	Water Use l/kkg of product (gal/1000 lb)	
Facility	Non-contact Cooling	Dust Suppression
1001	None	None
1002	None	None
1003	None	None
1004	None	None
1021	None	500
1022	8	None
1023	Unknown	16
1039	None	Unknown
1040	None	13
1212	None	None
1213	None	None
1215	290	8
1221	None	None
1974	17	60
5640	None	None

There is no distinction between wet and dry process pit pumpout. Neither frequency of flow nor pumping methods differ for a wet or dry process.

Water necessary for the washing operations is drawn from any one or combination of the following sources: quarries, wells, rivers, company owned ponds, and settling ponds. There is no set quantity of water necessary for washing crushed stone as the amount required is dependent upon the deposit from which the raw material is extracted. A deposit associated with a higher percentage of fine material will require a larger volume of water to remove impurities than one with a lower percentage of fines. A second factor affecting the amount of washwater is the degree of crushing involved. The amount of undesirable fines increases with the number of crushing operations, and consequently the greater the volume of water necessary to wash the finer grades of material.

Washwater

Facility	Percent of washed material	l/kkg of product (gal/ton)
5663	8	40 (10)
5640	15	670 (160)
1439	40	1050 (250)
1219	50	1250 (300)
1004	100	330 (80)
1003	100	690 (165)

Less than 10 percent of all crushed limestone operators dry their product or a portion of their product. Approximately 5 percent of these operators employ a wet scrubber in conjunction with the dryer as a means of air pollution control. Facility 1217 uses a rotary dryer approximately 30-40 percent of the total production time. At such time, the wet scrubber associated with this dryer utilizes water at the rate of 2,600 l/kkg of dried product (690 gal/ton).

Waste Water Treatment

Non-contact cooling water is generally discharged without treatment as is the case with facility 1974. Pit pumpout may either be discharged directly with no treatment (facility 1039), discharged following treatment (facility 5640), or discharged with the treated effluent from the washing operation (facility 1001). In the latter case, the quarry water may be combined with the untreated facility effluent and then flow through a settling pond system prior to discharge (facility 5662). The quarry water may instead join the semi-treated effluent as flow to the second of two settling ponds (facility 1213). There are many variations to the handling of pit pumpout by the wet processor. In general, however, the pit water is pumped through a settling pond system.

In all of the facilities contacted, the effluent from the washing operation is sent through a settling pond system prior to discharge. This system generally consists of at least two settling ponds in series designed to reduce the suspended solids in the final discharge. Facility 1439 utilizes two settling ponds to treat the washwater. The suspended solids concentration entering the first settling pond is 7000-8000 mg/l which is reduced to a level of 15-20 mg/l after flowing through the two ponds. Facility 3027 reports its settling pond system reduces the total suspended solid level in the facility washwater by 95 percent.

In some instances, flocculating agents are added to the waste stream from the wash facility prior to entering the first settling pond to expedite the settling of the fine particles. Facility 1222 uses such an agent. Mechanical equipment may be used in conjunction with a settling pond system in an effort to reduce the amount of solids entering the first pond. At facility 1040, the waste water from the washing operation flows through a dewatering screw which reportedly removes 50 percent of the solid material which represents a salvageable product. The waste water flows from the screw into the first settling pond.

Facility 1039 has an even more effective method for treating waste water from the washing operation. As with facility 1040, the waste water flows into a dewatering screw. Just prior to this step, however, facility 1039 employs a polymer injection system which releases a flocculating agent into the waste water. This enhances the action of the screw and leads to a higher salvage rate.

Effluents and Disposal

Waterborne waste discharges from facilities of this subcategory can consist of pit pumpout, non-contact cooling water, or process wash water plus pit pumpout. Where wash water is not discharged, it is completely recycled to the process. Of the facilities contacted that wash crushed stone, 33 percent do not discharge their wash water. Many of the remaining facilities recycle a portion of their waste water after treatment. It should be noted that evaporation and percolation have a tendency to reduce the flow rate of the final discharge in many instances. The main concern with the final effluent of a wet crushed stone operation is the level of suspended solids. This may vary greatly depending on the deposit, the degree of crushing, and the treatment methods employed.

The waste water from the wet scrubber in facility 1217 is sent to the first of two settling ponds in series. After flowing through both ponds, the water is recycled back to the scrubber with no discharge. Effluent data from some of the facilities that do discharge wash water after treatment by settling ponds are:

facility	effluent	source
1004	Flow - 8.7 x 10^6 l/day (2.30 mgd) pH - 7.5 Turbidity - 16 FTU	treated discharge composed of wash water (4%) and pit pumpout (96%)
1053	Flow - 1.8 x 10^6 l/day (0.48 mgd) pH - 8.4 Turbidity - 18 FTU	wash water after treatment
1218	Flow - 6.2 x 10^6 l/day (1.64 mgd) TSS - 20 mg/l	wash water after treatment then combined with pit pumpout

Of the facilities contacted the following are achieving total recycle of process generated waste water:

1002	1003	1039	1040
1062	1063	1064	1065
1066	1067	0168	1079
1070	1071	1072	1090
1161	1212	1220	1223
1439	3027	5663	

The following facilities use a common pond for process waste water and mine water. These facilities use much of this combined pond water for the total process water intake:

facility	effluent TSS mg/l
1001	8
1023	34
1219	2
1222	
1226	
1227	
1228	
5662	9
5664	40, 42

Many treatment ponds discharge less than the influent because of ground seepage. Facility 1974 is an example of a facility achieving no discharge because of seepage. Mine water discharge data from several facilities of this subcategory are:

facility	TSS mg/l
1001	3
1003	7
1004	12
1020	(1)5,(2)1
1021	14
1022	15
1023	34
1039	7
1040	25
1214	<1,2,3
1215	(1)42,(2)28
1219	2
1224	10-30
5660	14
5661	0
5663	1
5664	42.4

(1) first pit
(2) second pit

These discharges typically are not treated after removal from the pit sump.

Many of the operators in this subcategory must periodically clean their settling ponds of the fines which have settled out from wash water. A clamshell bucket is often used to accomplish this task. The fines recovered are sometimes in the form of a saleable product (facility 1215) while in most instances these fines are actually a waste material. In this instance, the material is either stockpiled or used as landfill (facilities 1053 and 1212). The quantity of waste materials entering the pond varies for each operator and the processes involved. Facility 1002 reports that the washwater entering the settling ponds is composed of 4-5 percent waste fines. The frequency of pond cleaning depends not only on the processes involved but also on the size of the pond. Facility 1217 must clean its settling ponds once per month, the recovered material serving as landfill. The disposal of these fines presents problems for many operators.

CRUSHED STONE, FLOTATION PROCESS

Process Description

Marble or other carbonaceous rock can be transported from the quarry to the processing facility where it is crushed, screened or wet milled and fed to flotation cells. Impurities are removed in the overflow and the pumped product is collected from the underflow. It is further wet milled to achieve a more uniform particle size, dried, and shipped. A process diagram is shown in Figure 14.

Raw Waste Load

Process raw wastes consist of clays and fines separated during the initial washing operations and iron minerals, silicates, mica, and graphite separated by flotation.

	kg/kkg of product (lb /1000 lb)	
waste	1975	3069
clays and fines	1,000	unknown
flotation wastes (solids)	50-100	50-100

In addition to the above, the flotation reagents added (organic amines, fatty acids and pine oils) are also wasted. The quantities of these materials are estimated to range from 0.1 to 1.0 kg/kkg of material.

Water Use

The water use for the three facilities is outlined as follows. There are considerable variations in process and mine pumpout waters.

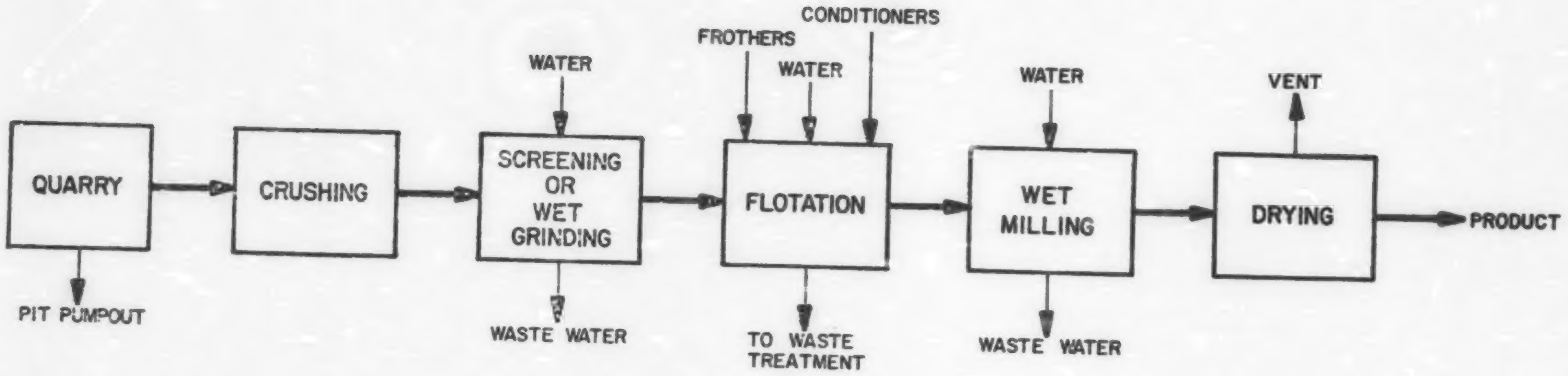


FIGURE 14
CRUSHED STONE MINING AND PROCESSING
(FLOTATION PROCESS)

Type	l/kkg of product (gal/ton) 1975	 3069	 1021
process	151,000 (36,000)	4,900 (1,170)	2,570 (610)
cooling	22,700 (5,400)	850 (200)	-----
dust control	1,510 (360)	1,400 (335)	
boiler	------	6,600 (1,580)	------
mine pumpout	unknown	none	16,000 (3,800)

*Facility 1975 also employs some of this "process" water to wash other materials.

Treatment

At facility 1975, all waste water is combined and fed to a series of settling lagoons to remove suspended materials. The water is then recycled back to other washing operations with the exception of about 5 percent which is lost by percolation and evaporation from the ponds. This loss is made up by the addition of fresh water.

At facility 1429 a considerable portion of the waste water is also recycled. The individual waste streams are sent to settling tanks for removal of suspended solids. From these, about 70 percent of the process water and all of the cooling and boiler water is recycled. The remainder is released to settling ponds for further removal of suspended solids prior to discharge.

At facility 1021, lagooning is also used for removal of suspended solids. Only at this facility is all water discharged.

Effluent

At facility 1975, there is no effluent. Ninety-five percent of the water is recycled and the remainder is lost by either evaporation or percolation in the ponds.

For facilities 3069 and 1021 the effluents are listed as follows along with corresponding intake water compositions. In the case of facility 1021 the data presented are analytical measurements made by the contractor.

	intake water (3069)	effluent (3069)	intake water (1021)	effluent (1021)	mine pumpout (1021)
TSS (mg/l)	5	10	3	4	8
BOD (mg/l)	1.0	<1.0	---	---	---
COD (mg/l)	1.0	<1.0	0	4	0
sulfate (mg/l)	3.5	<2.0	13	19	---
turbidity (FTU)	10	6	4	2	27
chloride (mg/l)	3.8	4.1	50	20	12
total solids (mg/l)	32	128	464	154	118

SHELL DREDGING

Process Description

Shell dredging is the hydraulic mining of semi-fossil oyster and clam shells which are buried in alluvial estuarine sediments. Extraction is carried out using self-contained floating hydraulic suction dredges which operate in open bays and sounds, usually several miles from shore. This activity is conducted along the coastal Gulf of Mexico and to a lesser extent along the Atlantic coast. Shell dredges are self-contained and support an average crew of 12 men working 12 hours/day in two shifts.

All processing is done on board the dredge and consists of washing and screening the shells before loading them on tow-barges for transport to shore. Shell is a major source of calcium carbonate along the Gulf Coast States and is used for construction aggregate and Portland cement manufacturing. Shell dredging and on-board processing is regulated under section 404 of the Act, Permits for Dredged or Fill Material.

CONSTRUCTION SAND AND GRAVEL (SIC 1442)

There are over 5,000 commercial operations, located in every state of the nation, extracting and processing construction sand and gravel. Three basic methods of sand and gravel extraction are practiced: (1) dry pit, removal above the water table; (2) wet pit, raw material extracted by means of a dragline or barge-mounted dredging equipment both above and below the water table; and (3) dredging, where sand and gravel is recovered from public waterways, including lakes, rivers, and estuaries. Once the raw material is extracted, methods of processing are similar for all cases, typically consisting of sand and gravel separation, screening, crushing, sizing, and stockpiling.

Based on one hundred facility visits and contacts (2 percent of the total), the industry was divided into the following subcategories:

(1) Dry process (10 facilities contacted)
(2) Wet process (80 facilities contacted)
(3) Dredging with on-land processing
    (7 facilities contacted)

These facilities are located in 22 states in all regions of the nation representing production levels from 10,800 kkg/yr (12,000 tons/yr) to over 1,800,000 kkg/yr (2,000,000 tons/yr). Facility ages varied from less than a year old to more than 50 years old.

SAND AND GRAVEL, DRY PROCESS

Process Description

After removal of the overburden, the raw material is extracted via front-end loader, power shovel or scraper and conveyed to the processing unit with conveyor belts or trucks. Specific methods vary with the nature and location of the deposit. At the processing facility, the sand is separated from the gravel via inclined vibrating screens and sized according to percent passing various screen openings. The larger sizes are used as a product or crushed and resized. The degree of crushing and sizing is highly dependent on the needs of the user. A typical process diagram is shown in Figure 15.

Raw Waste Loads

The raw wastes consist of oversize or undersize sand and gravel that is normally disposed of in worked-out pits. The amounts of these solid wastes are quite variable, depending

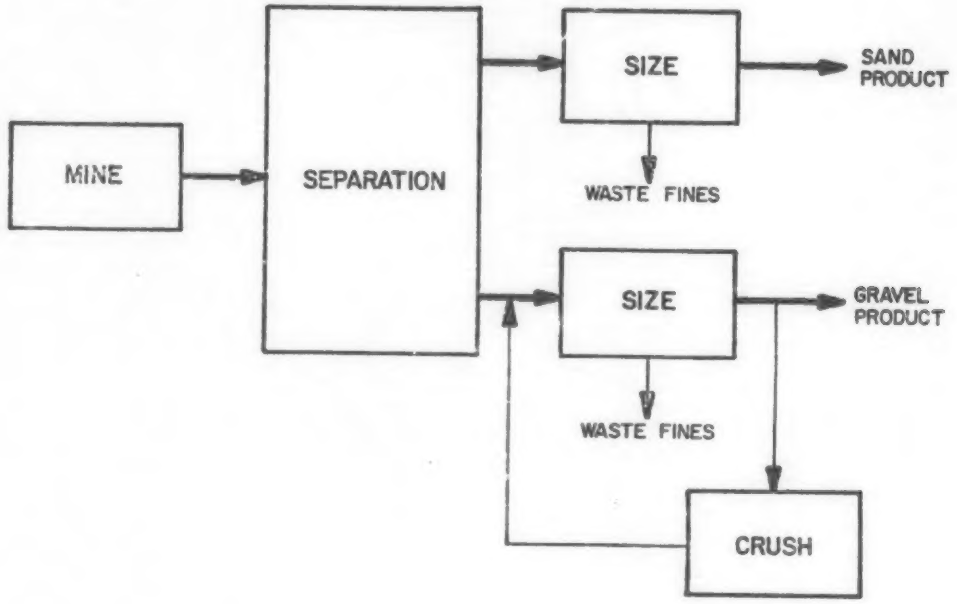


FIGURE 15
SAND AND GRAVEL MINING AND PROCESSING
(DRY)

on the quality of the deposits being processed. Some dry processing facilities are able to sell or utilize as much as 95 percent of the raw material, while others are able to sell less than 50 percent. The remainder is stockpiled or discarded as solid waste. The range of raw waste loads is from 50 to over 500 kg/kkg of raw material, or, in different terms, from 53 to over 1,000 kg/kkg of product.

Water Use

No water is used in the dry processing of sand and gravel. Mine pumpout may occur during periods of rainfall or, in the cases of portable or intermittent operations, prior to initial start-up. Most pumpouts occur when the water level reaches a predetermined height in a pit or low-area sump. Incidental water uses may include non-contact cooling water for crusher bearings and water for dust suppression. The following tabulates incidental water use at selected facilities:

	l/kkg of product (gal/ton)	
Facility	Non-contact cooling	Dust Suppression
1236	None	27.5 (6.6)
1231	None	16 (3.8)
1044	5 (1.2)	19 (4.5)

Waste Water Treatment

Mine pumpout and non-contact cooling water are typically discharged without treatment. Dust suppression water is adsorbed on the product and evaporated.

Effluents and Disposal

Facilities in this subcategory have no process water to discharge. Where effluents occur, they consist of pit pumpout and/or non-contact cooling water. At Facility 1044, only non-contact cooling water is discharged. Facility 1007 discharges pit water on a regular basis without any treatment. The pH of facility 1007 effluent ranges from 6.0-8.0, and the significant parameters are:

Flow, l/kkg of product (gal/ton)	625	(150)
TSS, mg/l	55	
TSS, kg/kkg of product (lb/ton)	0.034	(0.068)

SAND AND GRAVEL, WET PROCESS

Process Description

Sand and gravel operations requiring extraction from a wet pit or quarry typically use a dragline or a hydraulic dredge to excavate the material. The hydraulic dredge conveys the raw material as a wet slurry to the processing facility. After removal of the overburden, the raw material from a dry pit or quarry is extracted via front-end loader, power shovel or scraper, and conveyed to the processing facility on conveyor belts or in haul trucks.

Water in this subcategory is used to remove (wash) the clay or other impurities from the sand and gravel. State, local, and Federal specifications for construction aggregates require the removal of clay fines and other impurities. The sand and gravel deposits surveyed during this study ranged from 5 to 30 percent clay content.

Facility processing includes washing, screening, and otherwise classifying to size, crushing of oversize, and the removal of impurities. Impurities which are soluble or suspendable in water (e.g., clays) generally are washed out satisfactorily. These facilities are a combination of conveyors, screens, crushers, washing and classifying equipment, and storage and loading facilities. A typical wet processing facility would consist of the following elements:

(1) A hopper, or equivalent, receives material transported from the deposit. Generally, this hopper will be covered with a "grizzly" of parallel bars to screen out rocks too large to be handled by the facility.

(2) A scalping screen separates oversize material from the smaller marketable sizes.

(3) The material passing through the scalping screen is fed to a battery of screens, either vibrating or revolving, the number, size, and arrangement of which will depend on the number of sizes to be made. Water from sprays is applied throughout the screening operation.

(4) From these screens the different sizes of gravel are discharged into bins or onto conveyors for transportation to stockpiles, or in some cases, to crushers and other screens for further processing. The sand fraction passes to classifying and dewatering equipment and from there to bins and stockpiles. Screens are used to separate the sand from the gravel and to make required separation coarser than a -20 mesh sieve. Finer sizes of sand are produced by

classification equipment. Figure 16 illustrates a generalized flow diagram for a wet processing sand and gravel facility.

A small number of facilities must remove deleterious particles occurring in the deposit prior to washing and screening. Particles considered undesirable are classified as: soft fragments; thin and friable particles; shale; argillaceous sandstones and limestones; porous and unsound cherts; coated particles; coal; lignite and other low density impurities. Heavy-media separation (i.e., sink-float) is used for the separation of materials based on differing specific gravities. The process consists of floating out the lightweight material on a heavy "liquid" which is formed by suspension of finely ground heavy ferromagnetic materials such as magnetite and/or ferrosilicon in water. The "floated" impurities and the "sink" product (sand and gravel) are passed over a screen where the magnetite and/or ferrosilicon are removed by magnetic separation and recycled. The impurities are usually disposed of in nearby pits while the product is transported to the facility for routine washing and sizing. Figure 17 shows the heavy-media separation step used prior to the processing illustrated in Figure 16.

Raw Waste Loads

Raw wastes consist of waste fines composed of clays, fine mesh sands (usually less than 150 mesh), and other impurities. Oversize material is crushed to size and processed except in a few cases except where discarded. The amounts of these wastes are variable, depending on the nature of the raw material (i.e., percent of clay content) and degree of processing at the facility. Facility 1981, using heavy-media separation prior to wet processing, floats out 150 kg/kkg of the total raw material fed to the facility. The following lists the rate of raw waste generation at several other facilities:

Facility	kg/kkg of raw material (lb/1000 lb)
1006	140
1007	480
1055	50
1056	250
1391	80
3091	110

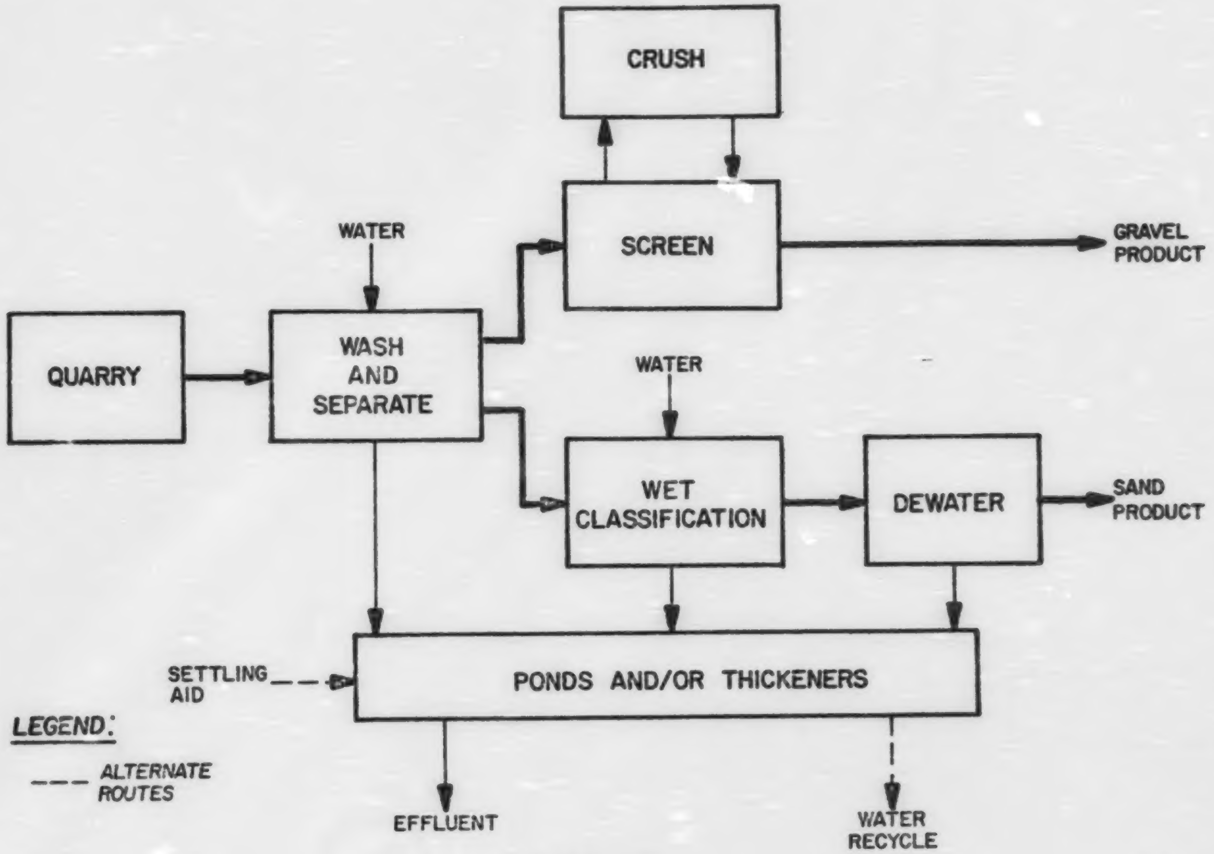


FIGURE 16
SAND AND GRAVEL MINING AND PROCESSING
(WET)

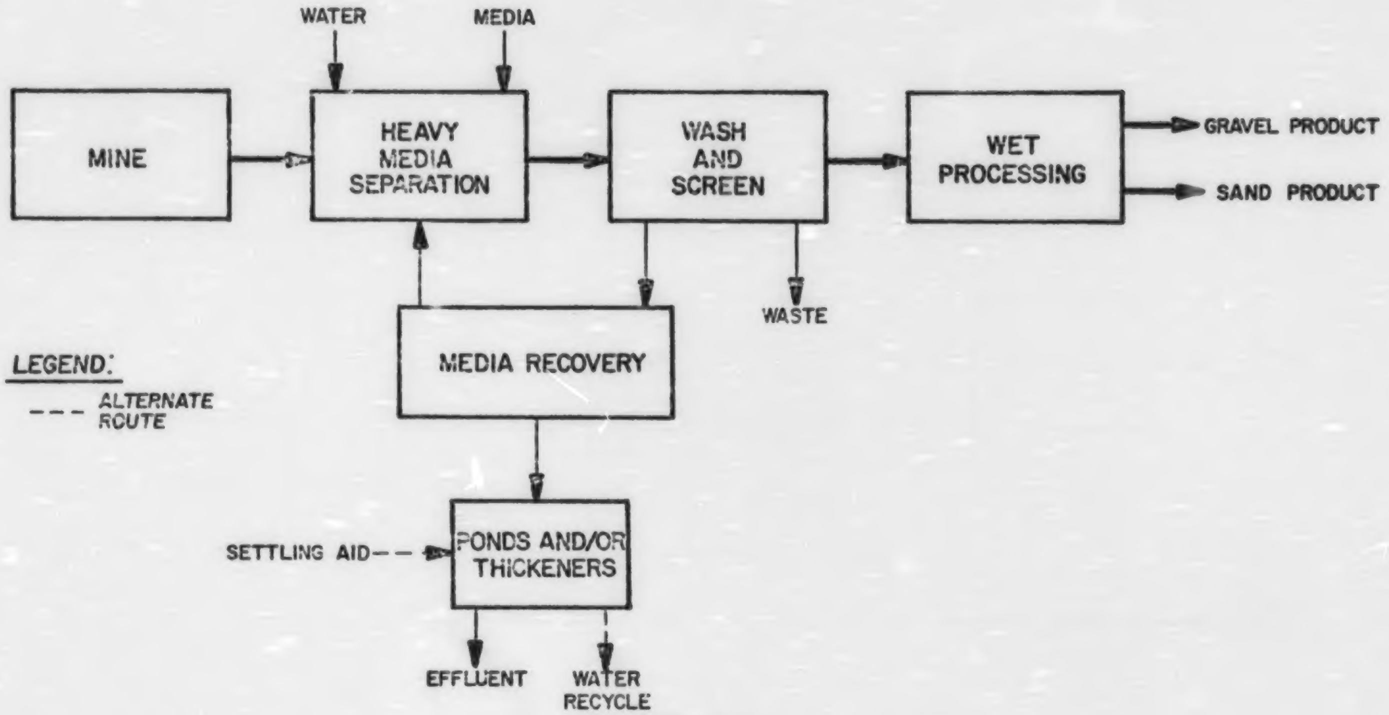


FIGURE 17
SAND AND GRAVEL MINING AND PROCESSING
(HMS)

Water Use

Process water includes water used to separate, wash, and classify sand and gravel. Incidental water is used for non-contact cooling and dust suppression. Water used for sand and gravel separation enters a rotary scrubber or is sprayed via spray bars onto a vibratory inclined screen to separate the sand and the clay from the gravel. The sand slurry is further processed via hydraulic classification where additional water is usually added. As the source of the raw material constantly changes, so does the raw waste load and the amount of water required to remove these wastes.

The following tabulates process water use at selected facilities:

Facility	l/kkg of product (gal/ton)
1006	2500 (600)
1012	9400 (2250)
1055	3400 (820)
1391	1430 (340)
5630	1460 (350)
5656	750 (180)
5666	7400 (1800)
5681	2000 (480)

Facilities 1012 and 5666 have markedly higher hydraulic loads than the others because they use hydraulic suction line dredges.

Facility 1006 discharges an average of 1900 l/min (500 gal/min) of pit water, or 208 l/kkg of product (50 gal/ton) ranging from 0 to 5000 l/kkg (0-1200 gal/ton) depending on the rainfall.

Waste Water Treatment

The predominant method of treating process waste water is to remove sand fines and clay impurities by mechanical dewatering devices and settling basins or ponds. Removal of -200 mesh sand and clay fines is much more difficult and requires settling times that are usually not achievable with mechanical equipment. Some facilities use settling aids to hasten the settling process. The best facilities in this subcategory are able to recycle the clarified water back to the process. Water with a total suspended solids content less than 200 mg/l is generally clean enough to reuse in the process. The following tabulates data from facilities which recirculate their process water resulting in no discharge of process waste water:

Facility	Input TSS (mg/l)	Treatment	Output TSS (mg/l)
1055	unknown	spiral classifiers, 4-hectares (10-acre) settling basin	25
1235	unknown	mechanical thickeners, settling ponds	54
1391	4,550	mechanical thickeners, cyclones, 2-hectares (5-acre) settling basin	32
1555	15,000	cyclones, 14-hectares (35-acre) settling basin	35
3049	5,000	cyclones, vacuum disc filter, 2-hectares (5-acre) settling pond with polymer floc	30
5617	unknown	dewatering screws, settling ponds	unknown
5631	unknown	dewatering screws, 10-hectares (25-acre) settling pond	unknown
5674	unknown	dewatering screws, 0.8-hectare (2-acre) settling pond	unknown

Facilities 1012 and 5666 are hydraulic dredging facilities. Slurry from these facilities is sent to a settling basin to remove waste fines and clays. The decant from the settling basin is returned to the wet pit to maintain a constant water level for the dredge resulting in no discharge of process water.

Lack of land to a major extent will impact the degree to which a facility is able to treat its process waste water. Many operations are able to use worked-out sand and gravel pits as settling basins. Some have available land for impoundment construction. The following lists the suspended solids concentration of treated waste water effluents from facilities discharging:

Facility	Treatment	TSS, mg/l
1006	dewatering screw, settling ponds	55
1044	dewatering screw, settling pond	154
1056	settling ponds	25
1083	dewatering screw, settling ponds	47
1129	dewatering screw, settling ponds	44
5630	dewatering screw, settling ponds	5

Facility 1981, using heavy-media separation, recovers the magnetite and/or ferrosilicon pulp, magnetically separates the media from the tailings, and returns the media to the process. Separation tailings from the magnetic separator are discharged to settling basins and mixed with process water.

Pit pumpout and non-contact cooling water are usually discharged without treatment. Facility 1006 discharges pit pumpout water through the same settling ponds which handle process water. Facility 1044 discharges non-contact cooling water through the same settling ponds used for treating process water. Dust suppression water is adsorbed on the product and evaporated.

Effluents and Disposal

Half the facilities visited are presently recirculating their process water resulting in no discharge.

Those facilities recirculating all process generated waste water include:

1007
1013
1014
1048
1055
1056
1057
1058
1059
1084
1200
1201
1202
1203
1204
1205
1206
1207
1208
1230
1233
1234
1236
1250
1391
1555
1629
3049
5622
5631
5656
5674

The following facilities achieve no discharge to navigable waters by perculation:

1231
1232
5666
5681

The following facilities previously mentioned as recycling all process generated waste waters declared that significant perculation occurs in their ponds:

1057
1058
1233
1234
5656

Facilities 1005, 1012, 5670 dredge closed ponds on their property and discharge all process waste waters back to the pond being dredged. Only very large rainfalls would cause a discharge from these ponds to navigable waters.

The rest discharge process water. Characteristics of some discharges are:

Facility	Flow l/kkg of product (gal/ton)	TSS kg/kkg of product (lb/1000 lb)
1006	2500 (600)	0.14
1044	1670 (400)	0.26
1056	1750 (420)	0.04
1083	1040 (250)	0.05
1129	1150 (275)	0.05
5630	1170 (290)	0.006

Solid wastes (fines and oversize) are disposed of in nearby pits or worked-out areas or sold. Clay fines which normally are not removed by mechanical equipment settle out and are routinely cleaned out of the settling pond. Facilities 1391 and 1629 remove clay fines from the primary settling pond, allow them to drain to approximately 20 percent moisture content, truck the wastes to a landfill site, and spread them out to enhance drying.

DREDGING WITH ON-LAND PROCESSING

Process Description

The raw material is extracted from rivers and estuaries using a floating, movable dredge which excavates the bottom sand and gravel deposit by one of the following general methods: suction dredge with or without cutter-heads, clamshell bucket, or bucket ladder dredge. After the sand and gravel is brought on-board, primary sizing and/or crushing is accomplished with vibrating or rotary screens, and cone or gyratory crushers with oversize boulders being returned to the water. The general practice in this subcategory is to load a tow-barge, which is tied alongside the dredge. The barge is transported to a land-based processing facility where the material is processed similar to that described for wet processing of sand and gravel. The degree of sand and gravel processing on-board the dredge is dependent on the nature of the deposit and customer demands for aggregate. Dredges 1010, 1052, 1051, extract the raw material via clamshell or bucket ladder, remove oversize boulders, size, and primary crush on-board. Figure 18 shows the basic material flow for these dredges. Dredges 1046 and 1048 extract via clamshell, but have no on-board crushing or sizing. The extracted material for all the above-mentioned dredges is predominantly gravel. This gravel must undergo numerous crushing and sizing steps on land to make a manufactured sand product which is absent in the deposit.

Dredges 1011 and 1009 excavate the deposit with cutter-head suction line dredges since the deposit is dominated by sand and small gravel. Dredge 1011 pumps all the raw material to an on-land processing facility. Dredge 1009, due to the lack of demand for sand at its location, separates the sand and gravel on-board the dredge with the sand fraction being returned to the river. The gravel is loaded onto tow-barges and transported to a land facility where wet processing is accomplished. The dredges in this subcategory vary widely in capital investment and size. Dredge 1046 consists of a floating power shovel powered by a diesel engine which digs the deposit and loads onto a tow-barge. A shovel operator and a few deck hands are on-board during the excavation which is usually only an eight-hour shift. Dredge 1009 is much larger and sophisticated since it requires partial on-board separation of sand and gravel. This dredge is manned by a twelve-man crew per shift, with complete crew live-in quarters and attendant facilities. This dredge operates 24 hours/day.

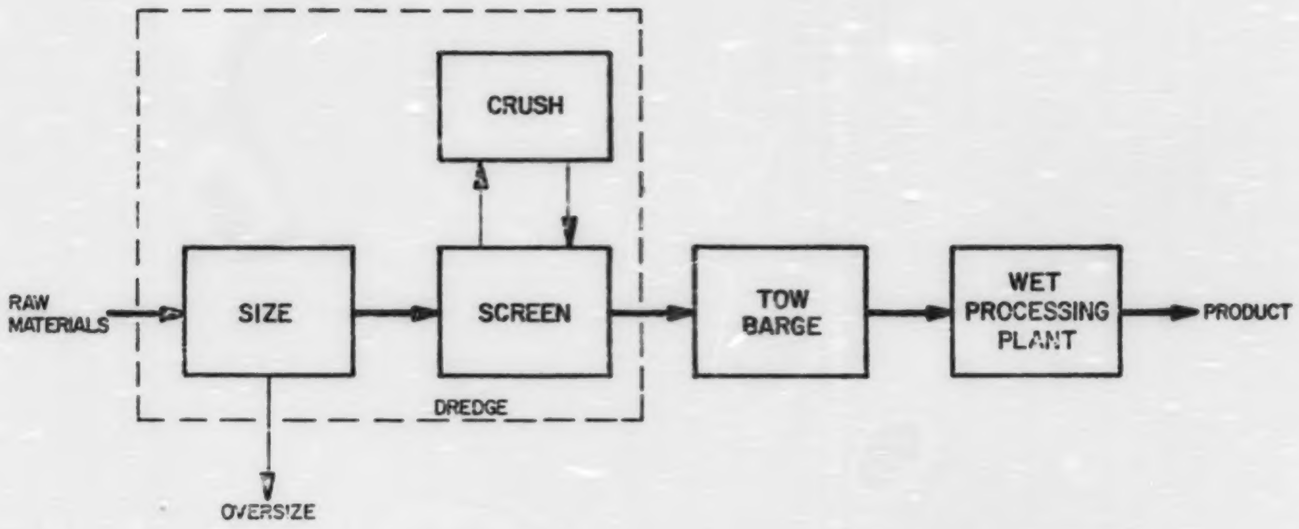


FIGURE 18
SAND AND GRAVEL MINING AND PROCESSING
(DREDGING WITH ON-LAND PROCESSING)

Raw Waste Loads

Raw wastes consist of oversize or unusable material which is discarded at the dredge and undersize waste fines (-150 mesh) which are handled at the land-based processing facility. The amount of waste material is variable depending on the deposit and degree of processing. On the average, 25 percent of the dredged material is returned to the river. Waste fines at land facilities average 10 percent. The following tabulates waste loads at selected operations:

Dredge	At Dredge kg/kkg of feed (lb/1000 lb)	At Land Facility kg/kkg of feed (lb/1000 lb)
1009	460	100
1010	none	400
1011	none	150
1046	none	110
1048	none	120
1051	250	60
1052	180	120

Clay content of dredged sand and gravel, usually averaging less than 5 percent, is less than that of land deposits due to the natural rinsing action of the river. Unsaleable sand fines resulting from crushing of gravel to produce a manufactured sand represent the major waste load at the land facilities.

Water Use

Water use at the land facilities is similar to wet processing subcategory facilities. the wet processing subcategory. Process water is used to separate, wash, and classify sand and gravel. Incidental water includes non-contact cooling and dust suppression. Water use at the dredge depends on the excavation method. Some clamshell and ladder bucket dredges do not use process water because there is no on-board washing. Suction line dredges bring up the raw material as a slurry, remove the aggregate, and return the water to the river. Water use at land facilities is variable depending on the raw material and degree of processing as shown below:

Facility	l/kkg of feed (gal/ton)
1009	2200 (530)
1010	1400 (340)
1046	1000 (240)
1048	3440 (825)
1051	1300 (320)
1052	1500 (360)

Water used for dust suppression averages 15 l/kkg (3.8 gal/ton) of gravel processed.

Waste Water Treatment

At dredge 1009, there is no treatment of the sand slurry discharged to the river. Removal of waste fines at land facilities with spiral classifiers, cyclones, mechanical thickeners, or rake classifiers and settling basins, is the method of process waste water treatment. These are similar to methods used in the wet processing subcategory. Facilities 1046, 1048, 1051 and 1052, by utilizing mechanical devices and settling basins, recirculate all process water thereby achieving no discharge. The following is a list of treatment methods, raw waste loads, and treated waste water suspended solids for these operations:

Facility	Raw Waste Load, TSS (mg/l)	Treatment	Treated Recycle Water, TSS (mg/l)
1046	8,500	dewatering screw, cyclone, drag classifier, settling basin	275
1048	10,000	dewatering screw, cyclones, settling basins	50
1051	9,000	dewatering screw, drag classifier, settling basin	300
1052	7,500	dewatering screw, drag classifier, settling basin with flocculants	200

Availability of land for settling basins influences the method of process water treatment. Many operations use worked-out sand and gravel pits as settling basins (Facility 1048) or have land available for impoundment. Facility 1010 is not able to recirculate under current conditions due to lack of space for settling basins. Land availability is not a problem at facilities 1011 and 1099.

Non-contact cooling water is typically discharged into the same settling basins used for treating process water. Dust suppression water is adsorbed onto the product and evaporates.

Effluents and Disposal

Four of the seven facilities visited in this subcategory have no discharge of process generated water. The remaining three discharge process washwater. Effluent parameters at two of these facilities are:

Facility	TSS mg/l	TSS, kg/kkg of product (lb/1000 lb)
1010	16,000	22
1009	50	0.10

Sand fines (+200 mesh) are removed with mechanical devices and conveyed to disposal areas. Clay fines and that portion of the silica fines smaller than 200 mesh, which settle out in a settling basin, are periodically dredged and stockpiled. Facility 1051 spends approximately 120 days a year dredging waste fines out the primary settling pond. These fines are hauled to a landfill area.

DREDGING WITH ON-BOARD PROCESSING

Process Description

The raw material is extracted from rivers and estuaries using a floating, movable dredge which excavates the bottom sand and gravel deposit by one of the following general methods: suction dredge, with or without cutter-heads, clamshell bucket, or bucket ladder dredge. After the sand and gravel is brought on-board, complete material processing similar to that described in the wet process subcategory, occurs prior to the loading of tow-barges with the sized sand and gravel. Typical on-board processing includes: screening, crushing of oversize, washing, sand classification with hydraulic classifying tanks, gravel sizing, and product loading. Numerous variations to this process are demonstrated by the dredges visited. Dredges 1017 and 1247 use a rotary scrubber to separate the sand and gravel which has been excavated from land pits, hauled to the lagoon where the dredge floats, and fed into a hopper ahead of the rotary scrubber. Dredge 1008 excavates with a revolving cutter head suction line in a deposit dominated by sand. The sand is separated from the gravel and deposited into the river channel without processing. Only the gravel is washed, sized, and loaded for product as there is little demand for sand at this location. Dredge 1050 employs bucket ladders, rough separates sand from gravel, sizes the gravel, crushing the oversize, and removes deleterious materials from the gravel by employing heavy media separation (HMS). HMS media (magnetite/ferrous silica) is recovered, and returned to the process. Float waste is discharged into the river. Dredge 1049, a slack-line bucket ladder dredge normally works a river channel. However, during certain periods of the year it moves into a lagoon where water monitors "knock down" the sand and gravel deposit into the lagoon in front of the buckets. All of the dredges pump river water for washing and sand classification. Periods of operation are widespread for the dredges visited. Dredge 1008 operates all year, 24 hours per day (two-12 hour shifts). Dredge 1049 operates two 8 hour shifts for 10 months. Dredging for sand and gravel is regulated under section 404 of the Act.

INDUSTRIAL SAND

The amount of industrial sand produced accounts for only 7 percent of the total U.S. sand production, but represents 20 percent of the total dollar value for all sand products. Sand produced for industrial purposes is used in the following areas: glassmaking, molding, grinding and polishing, blast sand, fire and furnace sand, locomotive traction sand, filtration, oil hydrofracture, or ground sand. The first two account for approximately 62 percent of the total industrial sand production, 37 and 25 percent respectively. The percentage of dollar values for each of the types of industrial sand correlate closely to their respective percentages of the production total. Forty states produce one or more categories of industrial sands with Illinois (16 percent), New Jersey (11.5 percent), and Michigan (10 percent) claiming 37.5 percent of the total output.

The three basic methods of extraction are:

(1) Mining of sand from open pits;
(2) Mining of sandstone from quarries; and
(3) hydraulic dredging from wet pits.

Once the raw material is extracted, the basic operations involved in the production of all types of industrial sand are classification and removal of impurities. The amount of impurities in the raw material is dependent upon the percentage of silica in the deposit. The subsequent level of technology involved in the removal of these impurities depends on the desired grade of product. Glass sand, for example, requires a higher degree of purity than does foundry sand.

Based on 15 facilities surveyed in seven states, the industry was divided into the following subcategories:

(1) Dry Process (5 facilities surveyed);
(2) Wet Process (4 facilities surveyed); and
(3) Flotation Process (6 facilities surveyed).

Two of the wet process facilities also use flotation on a small percentage of their finished product, and are included in the flotation process subcategory. Production, in the facilities contacted, ranges from 32,600 - 1,360,000 kkg/yr (36,000 - 1,500,000 tons/yr) and facility ages vary from less than one year to 60 years.

INDUSTRIAL SAND, DRY PROCESS

Process Description

Approximately 10 percent of the industrial sand operations fall into this subcategory, characterized by the absence of process water for sand classification and beneficiation. Typically, dry processing of industrial sand is limited to scalping or screening of sand grains which have been extracted from a beach deposit or crushed from sandstone. Facilities 1106 and 1107 mine a beach sand which has been classified into grain sizes by natural wind action on the deposit. Sand, of a specific grain size, is trucked to the facility where it is dried, cooled, coarse grain scalped, and stored. Processing of beach sand which is excavated at differing distances from the shoreline, enables the facility to process a number of grain sizes which can be blended to meet customer specifications.

Facilities 1109 and 1110 quarry a sandstone, crush, dry, and screen the sand prior to sale as a foundry sand. Facility 1108 is able to crush, dry, and screen a sandstone of high enough purity to be used for glassmaking. Most of the facilities use a dust collection system at the dryer to meet air pollution requirements. Dust collection systems are either dry (cyclones and baghouses in facilities 1106, 1109 and 1110) or wet (wet scrubbers in facilities 1107 and 1108). Figure 19 shows a typical process for dry mining and processing of industrial sand.

Raw Waste Loads

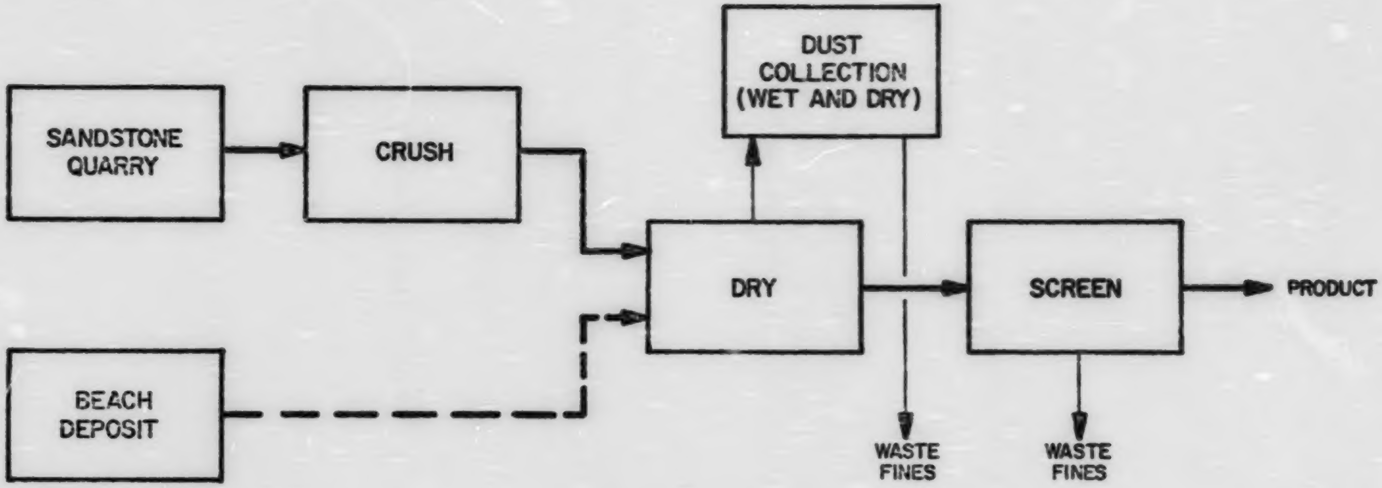
Raw wastes consist of oversize sandstone and undersize sand fines at facilities 1108, 1109, and 1110. Waste at these facilities averages less than 10 percent as shown below:

Facility	kg/kkg of feed (lb/1000 lb)
1108	100
1109	115
1110	92

Wastes at facilities 1109 and 1107 are undersize or coarse grained sand averaging about one percent of the feed to the facility.

Water Use

No water is used to wash and classify sand in this subcategory. Facilities 1108 and 1107 use a wet dust



LEGEND:

--- ALTERNATE ROUTE

FIGURE 19
INDUSTRIAL SAND MINING AND PROCESSING (DRY)

collection system at the dryer. Water flows for these two wet scrubbers are shown below:

Wet Scrubber Water Use	Facility 1107	Facility 1108
total flow, l/min (gal/min)	9460 (2500)	115 (30)
amount recirculated, l/min (gal/min)	9390 (2480)	0
amount discharged l/min (gal/min)	0	115 (30)
amount makeup, l/min (gal/min)	76 (20)	115 (30)

Although the five facilities surveyed in this subcategory did not use non-contact cooling water, it may be used in other facilities.

Waste Water Treatment

Wet scrubber water at facility 1108 is not treated prior to discharge. Scrubber water at facility 1107 is treated in a settling pond where suspended solids are settled and the clarified decant is returned to the scrubber, resulting in no discharge.

Effluents and Disposal

Facilities 1106, 1109, and 1110 do not have any waterborne wastes. Facility 1107 recirculates all wet scrubber water to the scrubber. Facility 1108 discharges wet scrubber water without any treatment as shown below:

Flow, l/day (GPD)	166,000 (43,000)
TSS, mg/l	33,000

Solid waste (oversize and sand fines) at all of the facilities is landfilled.

INDUSTRIAL SAND, WET PROCESS

Process Description

Mining methods vary with the facilities in this subcategory. Facility 3066 scoops the sand off the beach, while facility 1989 hydraulically mines the raw material from an open pit. Facility 1019 mines sandstone from a quarry. At this facility water is used as the transport medium and also for processing. Facility 1019 dry crushes the raw material prior to adding water. An initial screening is usually employed by most facilities consisting of a system of scalpers, trommels and/or classifiers where extraneous rocks, wood, clays, and other matter is removed. Facility 1102 wet mills the sand to produce a finer grade of material. At all facilities water is filtered off, and the sand is then dried, cooled, and screened. Facility 3066 magnetically separates iron from the dried product. The finished product is then stored to await shipment. Facility 3066 mines a feldspathic sand. This, however, does not require any special treatment nor different method of processing. A general wet process diagram for mining and processing of industrial sand is given in Figure 20.

Raw Waste Loads

At facility 3066, approximately one percent solid wastes (tree roots, rocks, clays, etc.) are separated from the sand. These amount to less than 0.5 kg/kkg (lb/1000 lb) of product. Both facilities 1102 and 1019 pump process waste materials, mainly clays, into their settling pond systems. This amounts to 30 and 36 kg/kkg respectively, of the material processed.

Water Use

There is no predetermined quantity of water necessary for washing industrial sands as the amount required is dependent upon the impurities in the deposit. Typical amounts of process water are given as follows:

Facility	l/kkg of product	(gal/ton)
1019	12,000	(2,880)
1102	7,260	(1,740)
1989	5,000	(1,200)
3066	170	(40)

Facility 1102 also uses water (quantity unknown) in a wet scrubber. Facility 1989 hydraulically mines the raw material using 3600 l/kkg of product (860 gal/ton). The remaining 1400 l/kkg of product (340 gal/ton) is used for

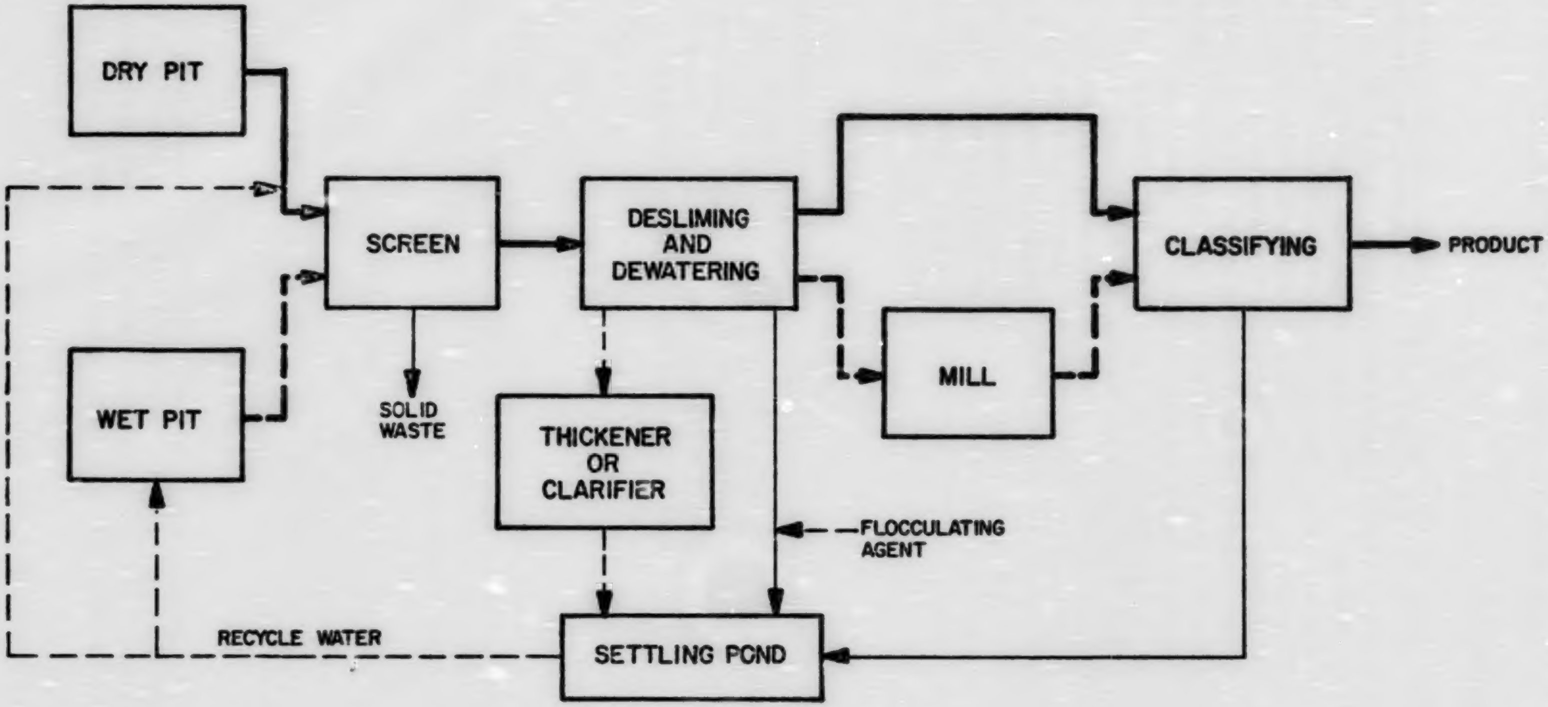


FIGURE 20
INDUSTRIAL SAND MINING AND PROCESSING
(WET)

washing and classifying. Incidental water use includes boiler and non-contact cooling water.

Waste Water Treatment

Under normal conditions facilities 1019, 1989, and 3066 are able to recirculate all process water by using mechanical devices and the settling of suspended solids in containment ponds. During periods of heavy rainfall, area runoff into the containment ponds cause a temporary discharge. Facility 1102 discharges process water, including wet scrubber water, after treatment in settling ponds. The treatment methods used by the facilities are shown as follows:

Facility	Treatment
1019	thickener, clarifier, containment pond
1102	cyclone, thickener and flocculant, settling ponds
1989	containment pond
3066	containment pond

Effluents and Disposal

There is no discharge of process water from three of the four facilities surveyed under normal operating conditions. Some facilities such as facility 1102, must periodically clean their settling ponds of the fines which have accumulated therein. The material recovered is either sold, stockpiled, or used as landfill.

INDUSTRIAL SAND, FLOTATION PROCESS

Process Description

Within this subcategory, three flotation techniques are used:

(1) Acid flotation to effect removal of iron oxide and ilmenite impurities,
(2) Alkaline flotation to remove aluminate bearing materials, and
(3) Hydrofluoric acid flotation for removal of feldspar.

In acid flotation, sand or quartzite is crushed, and milled into a fine material which is washed to separate adhering clay-like materials. The washed sand is slurried with water and conveyed to the flotation cells. Sulfuric acid, frothers and conditioning agents are added and the silica is separated from iron-bearing impurities. The reagents include sulfonated oils, terpenes and heavy alcohols in amounts of up to 0.5 kg/kkg (1 lb/ton) of product. In the flotation cells, the silica is depressed and sinks, and the iron-bearing impurities are "floated" away. The purified silica is recovered, dried and stockpiled. The overflow containing the impurities is sent to the wastewater treatment system.

In alkaline flotation, the process is very similar to that described above with the following difference: before the slurried, washed sand is fed to the flotation cell, it is pretreated with acid. In the cell, it is treated with alkaline solution (aqueous caustic, soda ash or sodium silicate), frothers and conditioners. The pH is generally maintained at about 8.5 (versus about 2 in acid flotation). Otherwise, the process is the same as for acid flotation. Materials removed or "floated" by alkaline flotation are aluminates and zirconates.

In hydrofluoric acid flotation operations, after the raw sand has been freed of clays by various washing operations, it is subjected to a preliminary acid flotation of the type described above. The underflow from this step is then fed to a second flotation circuit in which hydrofluoric acid and terpene oils are added along with conditioning agents to float feldspar. The underflow from this second flotation operation is collected, dewatered and dried. The overflow, containing feldspar, is generally sent to the waste water treatment system. A flowsheet for the three flotation processes is given in Figure 21.

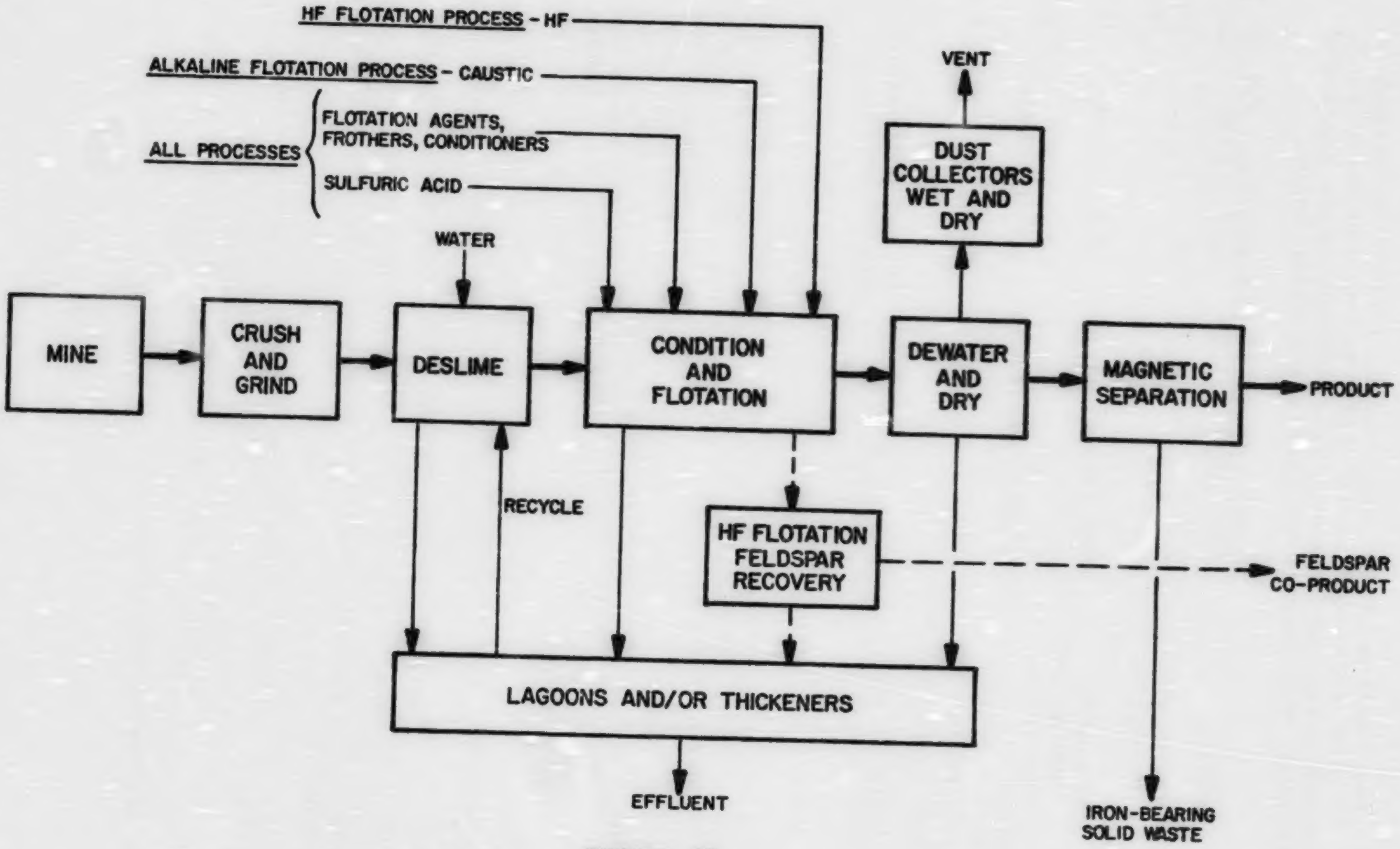

HF FLOTATION PROCESS - HF
ALKALINE FLOTATION PROCESS - CAUSTIC
ALL PROCESSES
FLOTATION AGENTS, FROTHERS, CONDITIONERS
SULFURIC ACID
WATER
VENT
DUST COLLECTORS WET AND DRY
MINE
CRUSH AND GRIND
DESLIME
CONDITION AND FLOTATION
DEWATER AND DRY
MAGNETIC SEPARATION
PRODUCT
RECYCLE
HF FLOTATION FELDSPAR RECOVERY
FELDSPAR CO-PRODUCT
LAGOONS AND/OR THICKENERS
EFFLUENT
IRON-BEARING SOLID WASTE

FIGURE 21
INDUSTRIAL SAND MINING AND PROCESSING
(FLOTATION PROCESSES)

Raw Waste Load

Process raw wastes from all three flotation processes consist of muds separated in the initial washing operations, iron oxides separated magnetically and materials separated by flotation. The amounts of wastes are given below.

		Amount kg/kkg of raw material (lb/1000 lb)					
Waste	Source	1101	1019	1980	1103	5691	5980
Clays	Washing	10	530	48	36	3	165
Flotation tailings	Flotation	50	20	60	140	17	135
Iron oxides	Magnetic separation	none	none	12 (24)	none	none	34
Acid & flotation agents*	Flotation	not given	not given	0.055 (0.11)	not given	not given	0.3
Fluorides (as HF)	HF Flotation tailings	none	none	none	none	none	0.45

* Generally flotation agents consist of oils and petroleum sulfonates and in some cases, minor amounts of amines.

Water Use

Facility water uses are shown below. Most of the water is recycled. The unrecycled portions of the waters for the alkaline and HF processes are those used for the flotation steps. For the acid flotation at least two facilities (1101 and 1980) have achieved total recycle. Facility 1019 impounds process discharge as wet sludge. Facility 1103 returns process waste water to the same wet pit where the raw material is extracted, adding make-up water for losses due to evaporation.

	l/kkg of product					
Facility	1101	1019	1980	1103	5691	5980
Process Recycle	25,400	2,580	23,200	27,300	8,400	24,200
Process Discharge	none	none*	none	6,830	5,250	1,760
Scrubber (recycle)	none	none	50 (10)	none	none	none
Total	25,400	2,930	23,250	34,130	13,650	26,060

* As impounded wet sludge

Waste Water Treatment

At the acid flotation facilities, facilities 1101, 1019, 1980, and 1103, all process wash and flotation waste waters are fed to settling lagoons in which muds and other suspended materials are settled out. The water is then recycled to the process. Facilities 1101 and 1980 are in their first year of operation.

At the alkaline flotation facility 5691, the washwaters are combined and fed to a series of settling lagoons to remove suspended materials and then partially recycled. Alum is used as a flocculating agent to assist in settling of suspended materials, and the pH is adjusted prior to either recirculation or discharge.

At facility 5980, the only facility found that uses HF flotation, all waste waters are combined and fed to a thickener to remove suspended materials. The overflow containing 93.2 percent of the water is recycled to the process. The underflow containing less than 7 percent of the water and essentially all of the suspended materials is fed to a settling lagoon for removal of suspended solids prior to discharge. The pH is also adjusted prior to discharge. Fluoride ion concentration in the settled effluent ranges from 1.5 to 5.0 mg/l.

Effluent and Disposal

Facilities 1101 and 1980 are presently producing products of a specific grade which allows them to totally recycle all their process water. In two other facilities, facilities 1019 and 1103, all facility waste waters leave the operations either as part of a wet sludge which is land disposed or through percolation from the settling ponds. There is no point source discharge from any of the acid flotation operations.

The composition of the intake and final effluent waters for the alkaline flotation facility 5691, are presented below. After neutralization of the added alkali and settling, the quality of the effluent is very similar to that of the intake.

Also shown below are the compositions of the intake and effluent for facility 5980, the HF flotation process facility.

Pollutants (mg/l)	Facility 5691		Facility 5980	
	Intake	Effluent	Intake	Effluent
pH	7.8	5.0	7.6	7.0-7.8
TDS	209	192	---	---
TSS	5	4	10	15-50
Sulfate	9	38	285	27-330
Oil and Grease	<1.0	<1.0	---	---
Iron	0.1	0.06	---	---
Nitrate	---	---	23	0-9
Chloride	---	---	62	57-76
Fluoride	---	---	0.8	1.8-4.6
Phenols	Not detectable			

GYPSUM

Although both underground mining and quarrying of gypsum is practiced, quarrying is the dominant method of extraction. General procedure for gypsum processing includes crushing, screening, and processing. An air-swept roller process facility is most commonly used for the latter. Two facilities use heavy media separation for beneficiation of a low-grade gypsum ore prior to processing. Ninety percent of all gypsum ore is calcined into gypsum products including wall board, lath, building plasters and tile. The remaining 10 percent is used as land plaster for agricultural purposes and in the cement industry for portland cement manufacturing. The manufacture of gypsum products is not covered in this report.

Thirty-six companies mined crude gypsum at 65 mines in 21 states in 1972. Five major companies operate 32 mines from which over 75 percent of the total crude gypsum is produced. Based on 5 facility visits and 36 facility contacts (63% of the total), the industry was divided into the following subcategories:

(1) Dry (3 visits, 32 contacts)
(2) Wet scrubbing (1 visit, 3 contacts)
(3) Heavy media separation (1 visit, 1 contact)

The facilities studied were in all regions of the nation representing various levels of yearly production and age.

GYPSUM, DRY PROCESS

Process Description

Underground mining is carried out in most mines by the room-and-pillar method, using trackless mining equipment. In quarrying, stripping is accomplished both with draglines and tractors. Quarry drilling methods are adapted to meet local conditions. Low-density, slow-speed explosives are employed in blasting. Loading is commonly done with diesel or electric shovels. Transportation may be by truck or rail from quarry to facility. Primary crushing is done at most quarries using gyratory and jaw crushers and impact mills. Secondary crushing is usually accomplished by gyratory units, and final crushing is almost exclusively by hammermills. The common unit for grinding raw gypsum is the air-swept roller process facility. Ground gypsum is usually termed "land plaster" since in this form it is sacked or sold as bulk for agricultural purposes. A typical process diagram is shown in Figure 22.

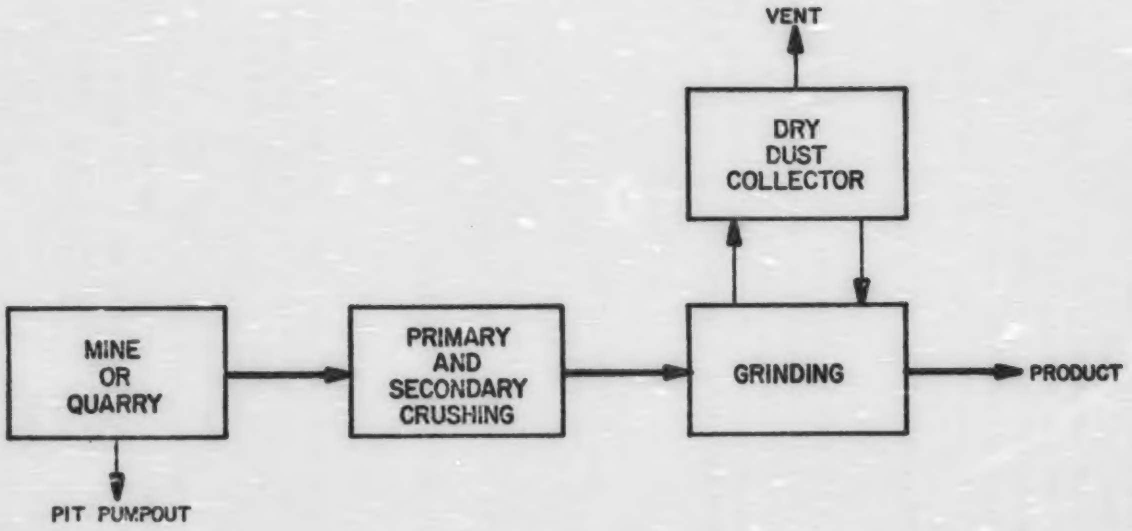


FIGURE 22
GYPSUM MINING AND PROCESSING
(DRY)

Raw Waste Loads

The raw wastes for all facilities consist of oversize material and gypsum dust from grinding. Many facilities work a gypsum deposit of such purity that all the ore fed to the crushers is ground to land plaster, except for a small percentage (<5%) lost to dust collection equipment (e.g. cyclones or bag houses). Facility 1977 discards 97,500 kkg/yr (1,075,000 tons/yr) of waste rock at the quarry site. This is 24 percent of the ore quarried.

Water Use

No process water is used in the mining, crushing, or grinding of gypsum. However, mine or quarry pumpout is necessary in a number of facilities. Pumpout is not related to a production unit of gypsum, and the flow is independent of facility processing capacities. Most pumpouts are controlled with a pit or low-area sump which discharges when the water level reaches a certain height. Incidental water use includes non-contact cooling water for crusher bearings. Facility data for non-contact cooling water use is given below:

Facility	l/kkg of product	(gal/ton)
1042	246	(59)
1700	58	(14)
1997	250	(60)
1999	4.5	(1)

Waste Water Treatment

Mine or quarry pumpout is generally discharged without treatment. Most facilities discharge non-contact cooling water without treatment.

Effluents and Disposal

There is no process generated waste water discharge except mine water discharge in this subcategory. Effluent data for some facilities discharging mine or quarry water are given as follows:

facility	flow, 10^6 l/day (mgd)	TSS, mg/l	pH
1041	4.4 (1.17)	6	7.7
1042	6.4 (1.70)	4	7.8
1112	5.1 (1.35)	14	8.1
1997	0.68 (0.18)	5	7.9
1999	6.5 (1.71)	24	7.4

Non-contact cooling water discharge from these facilities is given below:

facility	flow,l/kkg of product (gal/ton)	TSS mg/l	pH
1041	none	--	--
1042	246 (59)	not known	not known
1112	none	--	--
1997	250 (60)	6	7.9
1999	4.5 (1)	130	5

Land plaster dust collected in cyclones is either recycled to the process or hauled away and landfilled.

GYSPUM, WET SCRUBBING

Process Description

Facilities in this subcategory employ identical gypsum mining and processing methods as those used in the dry subcategory, except for the addition of wet scrubbers for air pollution control. Instead of dry dust collectors at the grinding mills (see Figure 22, facilities in this subcategory use wet scrubbers to remove land plaster dust created by hammerprocess facility operations.

Raw Waste Loads

Oversize wastes in this subcategory are similar to those in the dry subcategory. Land plaster waste fines are collected with wet scrubbers and discharged as a slurry. The amounts of raw waste fines so discharged from the scrubbers are:

facility	1776	1995	1998
kg/kkg of product (lb/1000 lb)	0.06	6.6	0.12

Wet scrubber make-up water for facility 1998 is sea water containing a high amount of dissolved and suspended solids.

Water Use

The only process water in this subcategory is that used for wet scrubbing. Quarry pumpout, while not found at the three facilities visited, is practiced by a number of facilities in this subcategory. Incidental water use includes non-contact cooling water for crusher bearings, as described in the dry subcategory. The following is water used for wet scrubbing at the facilities:

facility	l/kkg of product (gal/ton)
1776	2,230 (530)
1995	5,950 (1,430)
1998	2,780 (670)

Waste Water Treatment

Facilities 1998 and 1995 do not treat the wet scrubber discharge. Facility 1776 impounds the wet scrubber effluent prior to final discharge. Quarry pumpout water and non-contact cooling water usually receive no treatment prior to discharge.

Effuents and Disposal

Wet scrubber effluents are shown below:

facility	pH	TSS kg/kkg of product (lb/1000 lb)
1776	7.9	0.12
1995	unknown	6.6
1998	7.7	0.13

These are the total raw waste loads at facilities 1995 and 1998 and one-half of the raw waste load at facility 1776. Quarry pumpout and non-contact cooling water effluents and waste disposal are similar to those in the dry subcategory.

GYPSUM, HEAVY MEDIA SEPARATION

Process Description

Two facilities at the same general location beneficiate crude gypsum ore using heavy media separation (HMS) prior to processing. Both facilities follow the same process which includes quarrying, primary and secondary crushing, screening and washing, heavy media separation, washing, processing of float gypsum ore and stockpiling of sink dolomitic limestone. Magnetite and ferrous silica are used in both facilities as the separation media, with complete recirculation of the media or pulp. A process flow diagram is shown in Figure 23.

Raw Waste Loads

At facility 1100 raw waste consists of dolomitic limestone which is separated via heavy media separation, dewatered, and stockpiled for construction aggregate or landfill material. The amount of this waste is 500 kg/kkg (lb/1000 lb) of product. Additional wastes include fines generated during crushing which are washed out through screens, and allowed to settle in a settling basin. No information was available on the quantity of waste fines.

Water Use

Facility 1100 uses 1270 l/kkg (305 gal/ton) of ore processed in heavy media separation screening and washing which accounts for all process water. Additional water includes quarry pumpout. During periods of heavy rainfall, a discharge of up to 189,000 l/day (50,000 GPD) of quarry sump water may occur. As is typical with quarry pumpout, discharge is controlled by a sump, located at the low end of the quarry. Facility 1100 does not use non-contact cooling water for gypsum beneficiation.

Waste Water Treatment

All process water used for heavy media separation at facility 1100 and the one other facility in this subcategory is re-circulated through settling basins, an underground mine settling sump, and returned to the separation circuit, resulting in no discharge of process waste water. In the recycle circuit, the HMS media (magnetite/ferrous silica) is reclaimed and is reused in the separation process. Quarry pumpout at facility 1100 is discharged to a settling ditch which flows to a company owned marsh prior to discharge, thereby achieving an effective settling of suspended solids.

Effluents and Disposal

There is no waterborne process water effluent in this subcategory. At facility 1100, only quarry water is discharged intermittently shown below:

l/day (GPD)	0-189,000 (0-50,000)
TSS, mg/l	60
pH	7.8

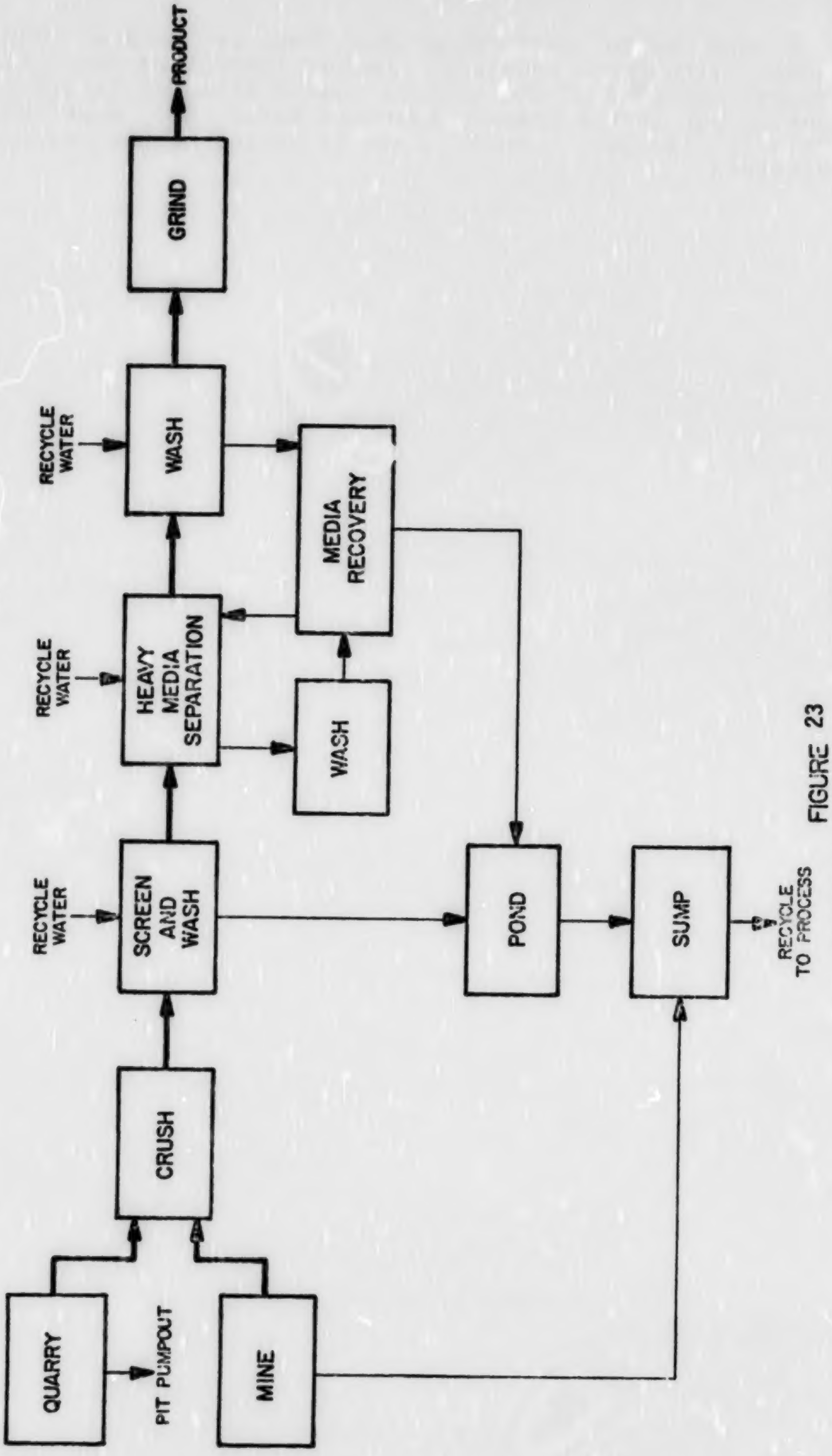


FIGURE 23
GYPSUM MINING AND PROCESSING
(HMS)

Part of the waste rock from the HMS is sold as road aggregate, with the remainder being landfilled in old worked-out sections of the quarry. Waste fines at facility 1100 settle out in the primary settling basin and must be periodically dredged. This waste is hauled to the quarry and deposited.

ASPHALTIC MINERALS (SIC 1499)

This category of materials encompasses three basic types of materials produced by three different processes:

(1) bituminous limestone which is dry quarried;
(2) oil impregnated diatomite produced by dry methods;
(3) gilsonite and other bituminous shales produced by wet processes.

BITUMINOIUS LIMESTONE

Process Description

Bituminous limestone is dry surface mined, crushed, screened and shipped as product. A process flow sheet is given in Figure 24.

Raw Waste Load

The raw wastes from these operations consist entirely of overburden removed during the mining operations. This material is a solid waste and amounts to 300 kg/kkg of product.

Water Usage, Treatment and Effluent

No water is used in these operations, and hence there is no need for waste water treatment and no waterborne effluent.

OIL IMPREGNATED DIATOMITE

Process Description

This material is produced at only one site. Oil impregnated diatomite is surface mined, crushed, screened and then calcined (burned) to free it of oil. The calcined material is then ground and prepared for sale. The only process water usage is a wet scrubber used to treat the vent gases from the calcination step. The scrubber waters are recycled. A process flowsheet is given in Figure 25.

Raw Waste Load

There are no process solid or waterborne wastes.

Water Use

Facility water use consists of 1800 l/kkg (420 gal/ton) of product for scrubber makeup water. The scrubber water is lost by evaporation.

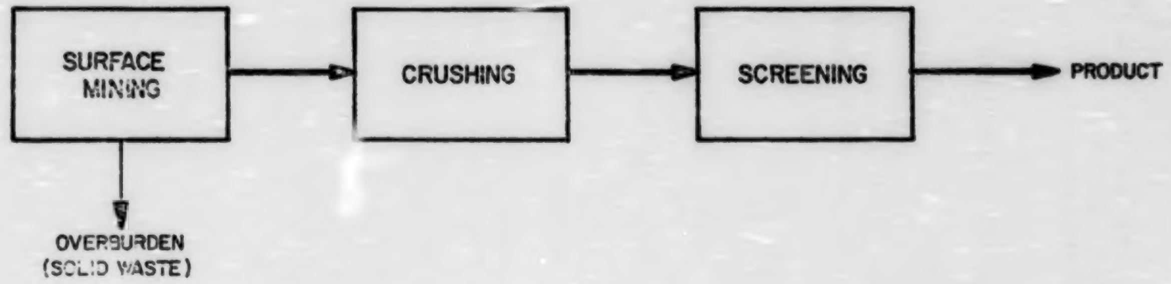


FIGURE 24
BITUMINOUS LIMESTONE MINING AND PROCESSING

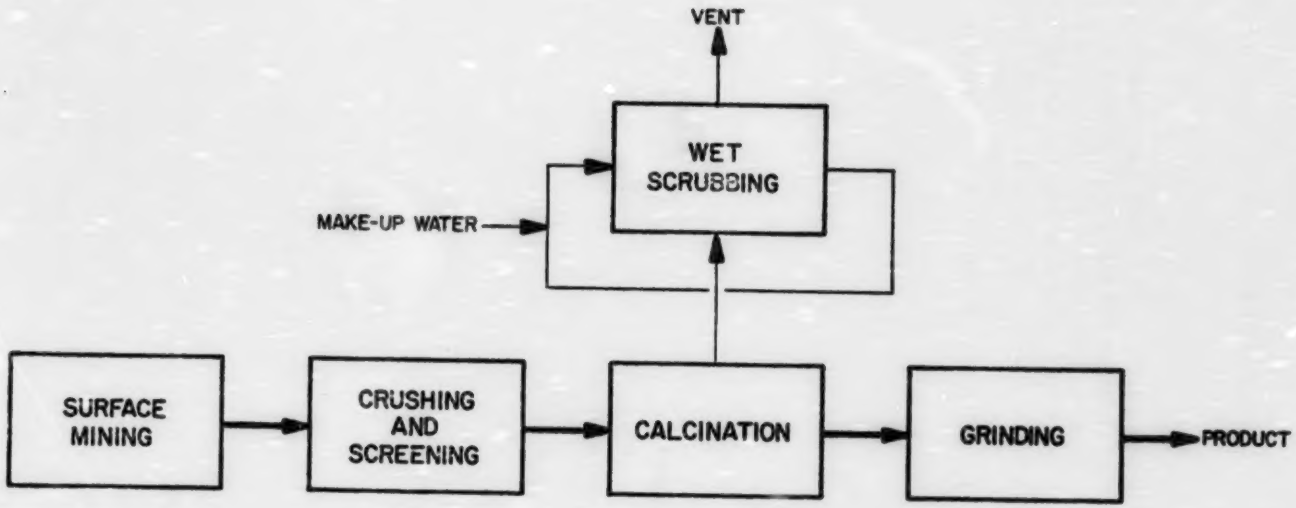


FIGURE 25
OIL IMPREGNATED DIATOMITE MINING AND PROCESSING

Treatment and Effluent

There is no treatment required as there is no waterborne effluent.

GILSONITE

Process Description

Gilsonite is mined underground. The ore is conveyed to the surface as a slurry and separated into a gilsonite slurry and sand, which is discarded as a solid waste. The gilsonite slurry is screen separated to recover product. Further processing by centrifuge and froth flotation recover additional material. These solids are then dried and shipped as product. A process flowsheet is given in Figure 26.

Raw Waste Load

Raw wastes consist of sand, process water and mine pumpout waters.

Water Use

Facility water use is given below. A considerable amount of intake water is used for non-process purposes (i.e., drinking and irrigation). All process and mine pumpout waters are currently discharged.

	l/kkg of product (gal/ton)
intake	5,700 (1,400)
process	3,400 (820)
mine pumpout	470 - 1,800 (110-430)
drinking and irrigation	2,300 (550)

Effluent

The compositions of the intake water, the discharged facility process water and the mine pumpout water are listed below. There is a considerable concentration of suspended solids in the mine pumpout water. These discharges are currently being eliminated. The process and mine pumpout waters currently discharged will soon be employed on site for other purposes.

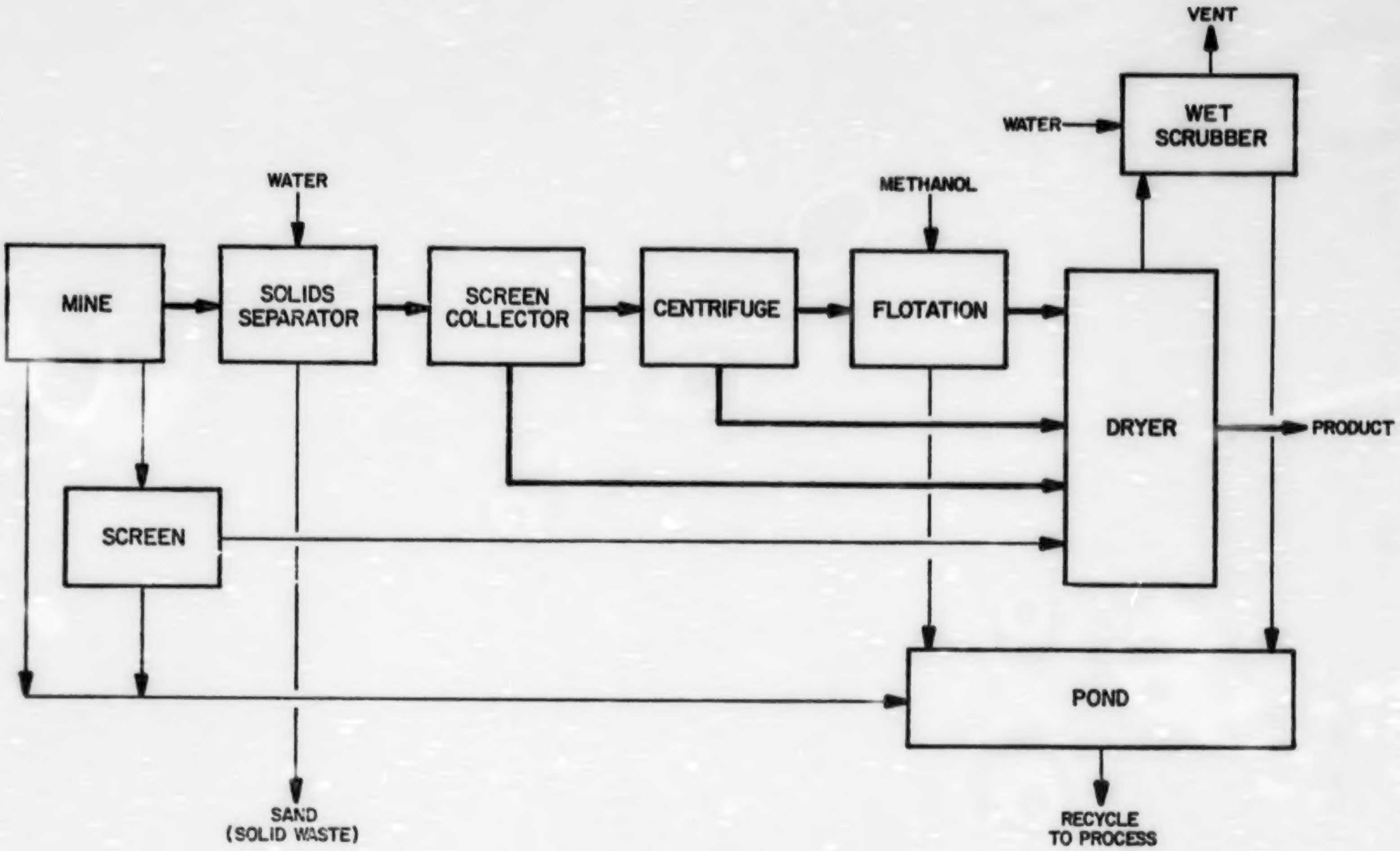


FIGURE 26
GILSONITE MINING AND PROCESSING

	Concentration (mg/l)		
	intake	effluent	mine pumpout
Suspended solids	33	17	3375
BOD	35	43	12
pH	7.7	8.2	7.9 - 8.1
TDS	401	2949	620
Turbidity	--	--	70 JTU
Arsenic	--	--	0.01
Barium	--	--	<0.01
Cadmium	--	<0.001	0.004
Chloride	--	0.15	8.8
Sulfate	--	363	195

ASBESTOS AND WOLLASTONITE

ASBESTOS (SIC 1499)

Four states produce asbestos; California, with 69% of the total production, is the leader, followed in order by Vermont, Arizona, and North Carolina. The California and Vermont facilities mine a chrysotile asbestos, while the North Carolina deposit is an anthophyllite asbestos. Major uses for asbestos fiber include construction, floor tile, friction products, paper and asphalt felts.

Processing of asbestos ore principally involves repeated crushing, fiberizing, screening, and air separation. Five facilities mine and process asbestos in the United States. Based on information from all five facilities two subcategories are established for asbestos mining and processing:

(1) Dry processing asbestos (4 facilities)
(2) Wet processing asbestos (1 facility)

ASBESTOS, DRY PROCESS

Process Description

Asbestos ore is usually extracted from an open pit or quarry. At three facilities the fiber-bearing rock is removed from an open pit. At facility 1061 the ore is simply "plowed", allowed to air-dry, and the coarse fraction is screened out from the millfeed.

After quarrying, the asbestos ore containing approximately 15% moisture is crushed, dried in a rotary dryer, crushed, then sent to a series of shaker screens where the asbestos fiber are separated from the rock and air classified according to length into a series of grades. The collection of fibers from the shaker screens is accomplished with cyclones, which also aid in dust control. Figure 27 illustrates process flow for a dry asbestos operation.

Raw Waste Loads

Asbestos processing involves fiber classification based on length, and as such, the raw waste loads consist of both oversize rock and undersize asbestos fibers which are unusable due to their length (referred to as "shorts"). At facility 1061 28 percent of the asbestos ore is rejected as oversize waste. At the processing facility another 65 percent of the feed are unusable asbestos fiber wastes which must be disposed of.

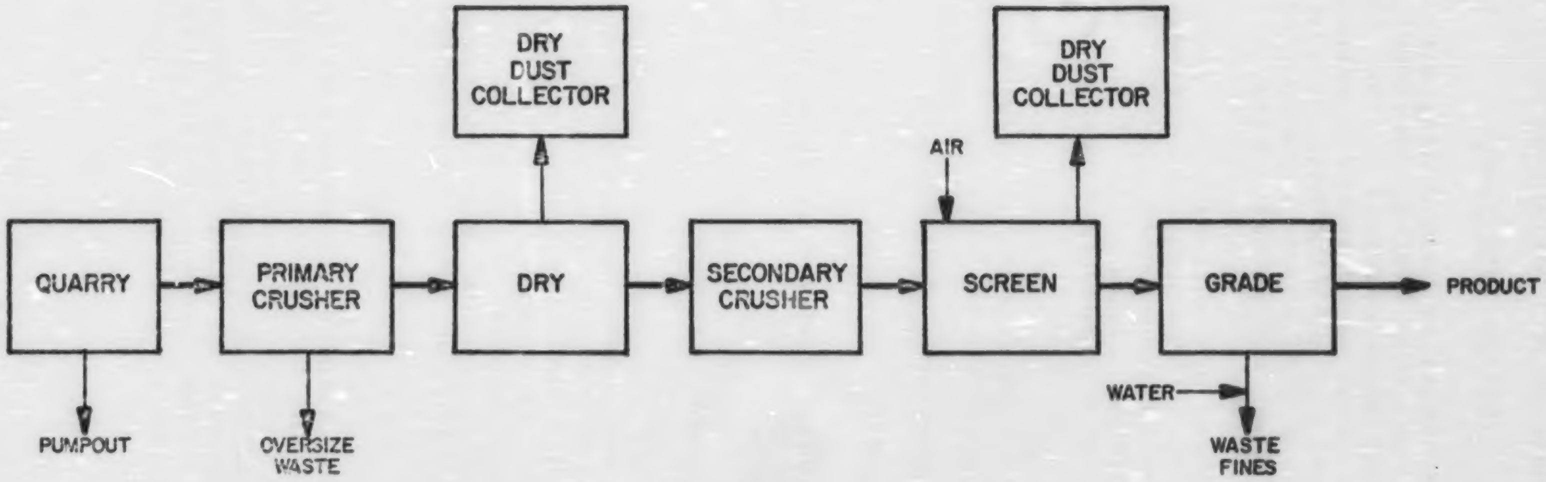


FIGURE 27
ASBESTOS MINING AND PROCESSING
(DRY)

Water Use

No process water is used for the dry processing of asbestos at any of the four facilities in this subcategory. Facility 3052 must continuously dewater the quarry of rain and ground water that accumulates. The flow is from 380 l/min to 2270 l/min (100 to 600 gal/min) depending on rainfall. The quantity of discharge is not related to production rate of asbestos. Facility 1061 uses water for dust suppression which is sprayed onto the dry asbestos tailings to facilitate conveying of tailings to a waste pile. The water absorbed in this manner amounts to 17 l/kkg of tailings (4 gal/ton).

Waste Water Treatment

Facility 3052 treats their quarry pumpout discharge with sulfuric acid (approximately 0.02 mg/l of effluent) to lower the pH of the highly alkaline ground water that collects in the quarry. At all facilities, both at the mine and facility site, there exists the potential of rainwater runoff contamination from asbestos waste tailings. Facility 1061 has constructed diversion ditches, berms, and check dams to divert and hold area runoff from the waste tailing pile. Due to soil conditions, water that collects in the check dams eventually percolates into the soil thereby resulting in no discharge to surface waters.

Effluents and Disposal

Facility 3052 discharges quarry pumpout water on a continuous basis. The following tabulates analytical data for facility 3052's quarry discharge after treatment with H_2SO_4:

flow, l/day (mgd)	545,000-3,270,000 (0.144-0.864)
TSS, mg/l	2.0
Fe, mg/l	0.15
pH	8.4-8.7
asbestos (fibers/liter)	$1.0 - 1.8 \times 10^6$

Waste asbestos tailings are stockpiled at all facilities.

ASBESTOS, WET PROCESS

Process Description

The only facility in this subcategory, facility 1060, mines the asbestos ore from a quarry located approximately 50 miles from the processing facility. The ore is "plowed" in horizontal benches, allowed to air-dry, coarse fractions screened out, and transported to the facility for processing. At the facility, processing consists of screening, wet crushing, fiber classification, filtering, and drying. Figure 28 illustrates process flow at facility 1060.

Raw Waste Load

Raw waste consists of oversize rock which is discarded at the quarry site and undersize waste asbestos ("shorts") which are unsaleable. The undersize waste fibers represent 30 percent of the total ore processed. No data on amount of oversize wastes were available.

Water Use

Process water is used for wet processing and classifying of asbestos fibers. Facility 1060 uses 4,300 l/kkg (1,025 gal/ton) of asbestos milled. Approximately 4 percent of the water is incorporated into the end product which is a filter cake of asbestos fibers (50% moisture by weight). Eight percent is lost in the tailings disposal. Sixty eight percent is recirculated back into the process, and 20 percent is eventually discharged from the facility. The following tabulates estimated process water use at facility 1060:

	l/kkg of feed	(gal/ton)
process water	4,300	(1,025)
water lost with product	150	(36)
water lost in tailings	350	(84)
water recirculated	2,900	(700)
water discharged to settling pond	860	(205)

This facility is unable to recirculate the water from the settling pond because of earlier chemical treatment given the water in the course of production of a special asbestos grade. The recirculation of this effluent would affect the quality of the special product. In addition to process water, facility 1060 uses 2,100 l/kkg of feed (500 gal/ton) of non-contact cooling water, none of which is recirculated.

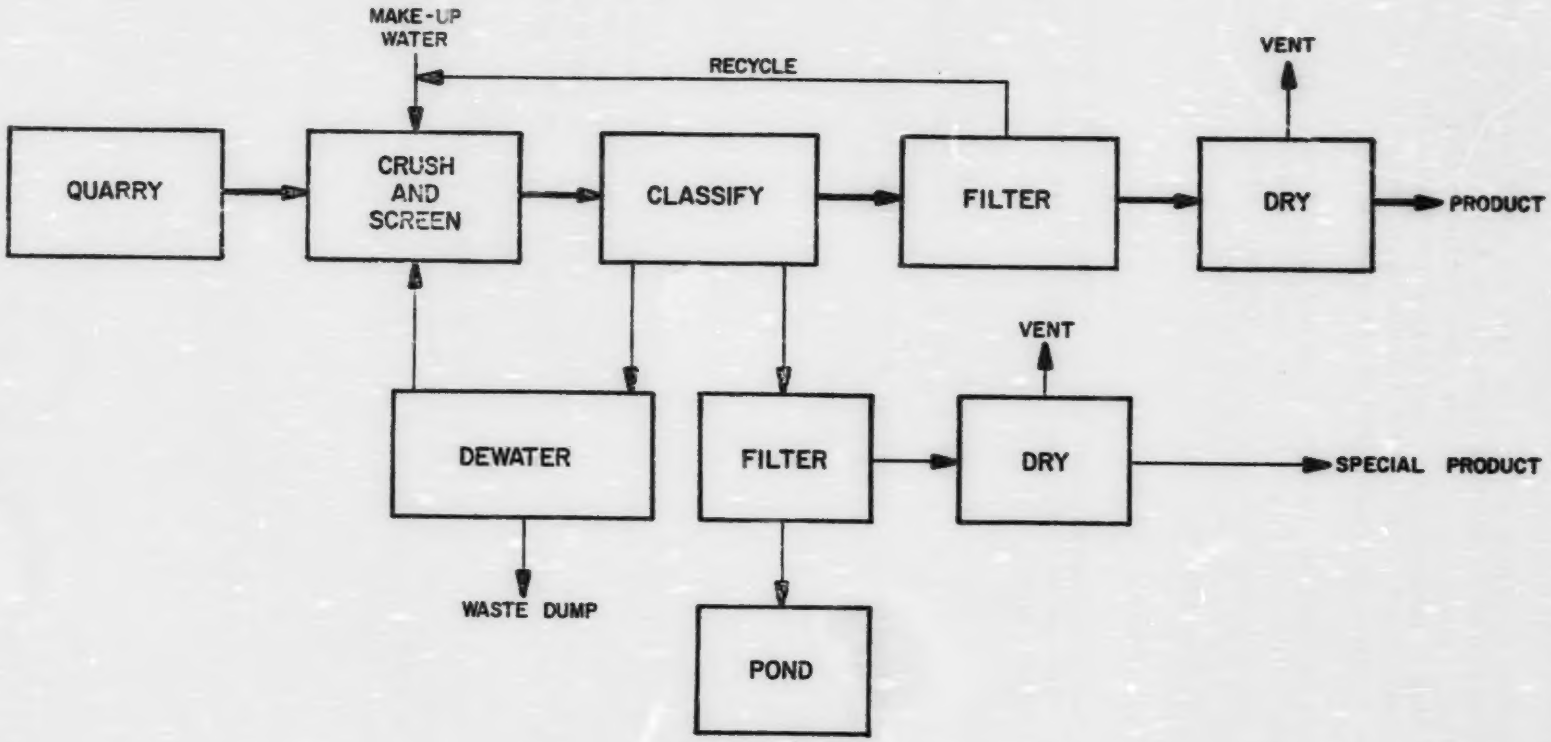


FIGURE 28
ASBESTOS MINING AND PROCESSING
(WET)

Waste Water Treatment

The process water discharge is treated in settling/percolation ponds. Suspended asbestos fibers settle out in the primary settling pond prior to decanting the clarified effluent to the secondary settling/percolation pond. Facility 1060 does not discharge to surface waters but uses percolation as a form of waste water treatment.

Non-contact cooling water is not treated prior to discharge. Runoff from asbestos tailings at the facility and the quarry is controlled with diversion ditches, berms, and check dams. All facility drainage is diverted to the settling/percolation ponds.

Effluents and Disposal

No process water is discharged to surface water at facility 1060. Data on the waste stream to the percolation pond includes the following:

	Intake Well Water	Discharge to Percolation Pond
flow, l/kkg feed(gal/ton)	unknown	856 (205)
total solids, mg/l	313	1,160
pH	7.5	7.8
magnesium, mg/l	14	48
sodium, mg/l	44	345
chloride, mg/l	19	104
nickel, mg/l	0.02	0.1

Asbestos fiber tailings are stockpiled near the facility where the water is drained into the settling/percolation ponds. After some drying, the tailings are transported and landfilled near the facility in dry arroyos or canyons. Check dams are constructed at the lower end of these filled-in areas.

The primary settling pond must be periodically dredged to remove suspended solids (primarily asbestos fibers). This is done with a power shovel, and the wastes are piled alongside the pond, allowed to dry, and landfilled.

WOLLASTONITE (SIC 1499)

There is only one producer of wollastonite in the U.S.

Process Description

Wollastonite ore is mined by underground room and pillar methods, and is trucked to the processing facility. Processing is dry and consists of 3 stage crushing, with drying following primary crushing. After screening, various sizes are fed to high-intensity magnetic separators, to remove garnet and other ferro-magnetic impurities. The purified wollastonite is then ground in pebble or attrition mills to the desired product sizes. A general process diagram is given in Figure 29.

Raw Waste Load

Of the total amount of wollastonite ore mined, approximately 50 percent, or 70,000 - 80,000 tons/yr, is waste. This waste material is stocked for future use. In wollastonite processing, waste is generated in the magnetic separators, with garnet and some sand being sold as by-products. The rest is sent to a waste pile.

Water Use

Municipal water serves as the source for the sanitary and non-contact cooling water used in the facility. This amounts to 235 l/kkg of product (56 gal/ton).

Waste Water Treatment

Non-contact cooling water is discharged with no treatment to a nearby river.

Effluent and Disposal

Solid wastes generated in mining are stocked and eventually used. Processing wastes are sent to a waste pile, with garnet and some sand sold as by-product. Non-contact cooling water is discharged untreated. The limitations on this discharge as established by the Federal discharge permit are:

	Average	Min.-Max.
Temperature	11°C (52°F)	10-17°C (51-62°F)
pH		6 - 9

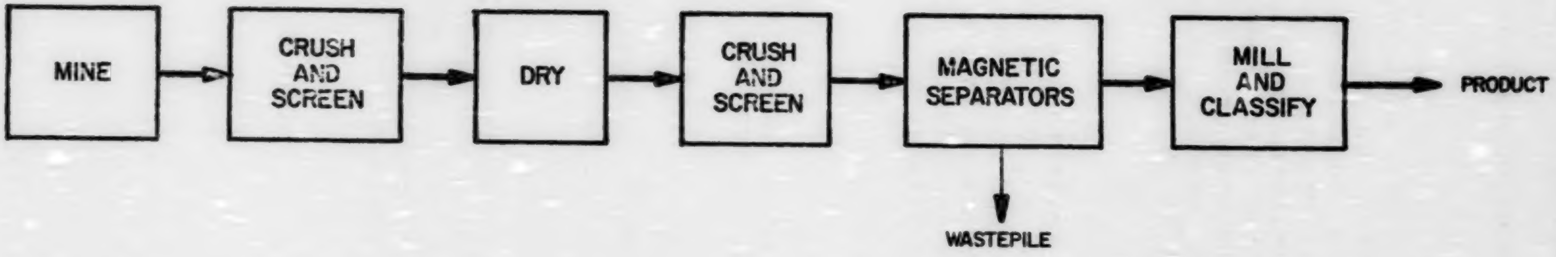


FIGURE 29
WOLLASTONITE MINING AND PROCESSING

LIGHTWEIGHT AGGREGATE MINERALS (SIC 1499)

PERLITE

New Mexico produces 87 percent of the U.S. crude perlite. Three of four major perlite producers in New Mexico were visited and analyzed. All U.S. perlite facilities are in the same geographic region, and the processes are all dry.

Process Description

All the operations are open pit quarries using either front-end loaders or blasting to remove the ore from the quarry. The ore is then hauled by truck to the mills for processing. There the ore is crushed, dried, graded (sized), and stored for shipping. A general process diagram is given in Figure 30.

Perlite is expanded into lightweight aggregate for use as construction aggregate, insulation material, and filter medium. Expansion of perlite is accomplished by injection of properly sized crude ore into a gas- or oil-fired furnace with the temperature above 760°C (1,400°F). The desired temperature is the point at which the specific perlite being processed begins to soften to a plastic state and allows the entrapped water to be released as steam. This rapidly expands the perlite particles. Horizontal rotary and vertical furnaces are commonly used for expanding perlite. In either case, there is no process water involved. Horizontal rotary furnaces occasionally require non-contact cooling water for bearings.

Raw Waste Load

Waste is generated both in the mining and processing processes. In the mining of perlite, oversize materials too large for the primary crushers are discarded. In the processing process fines are generated from screening operations and airborne dust and fines are collected in baghouses. The nature and amounts of raw wastes generated are as follows:

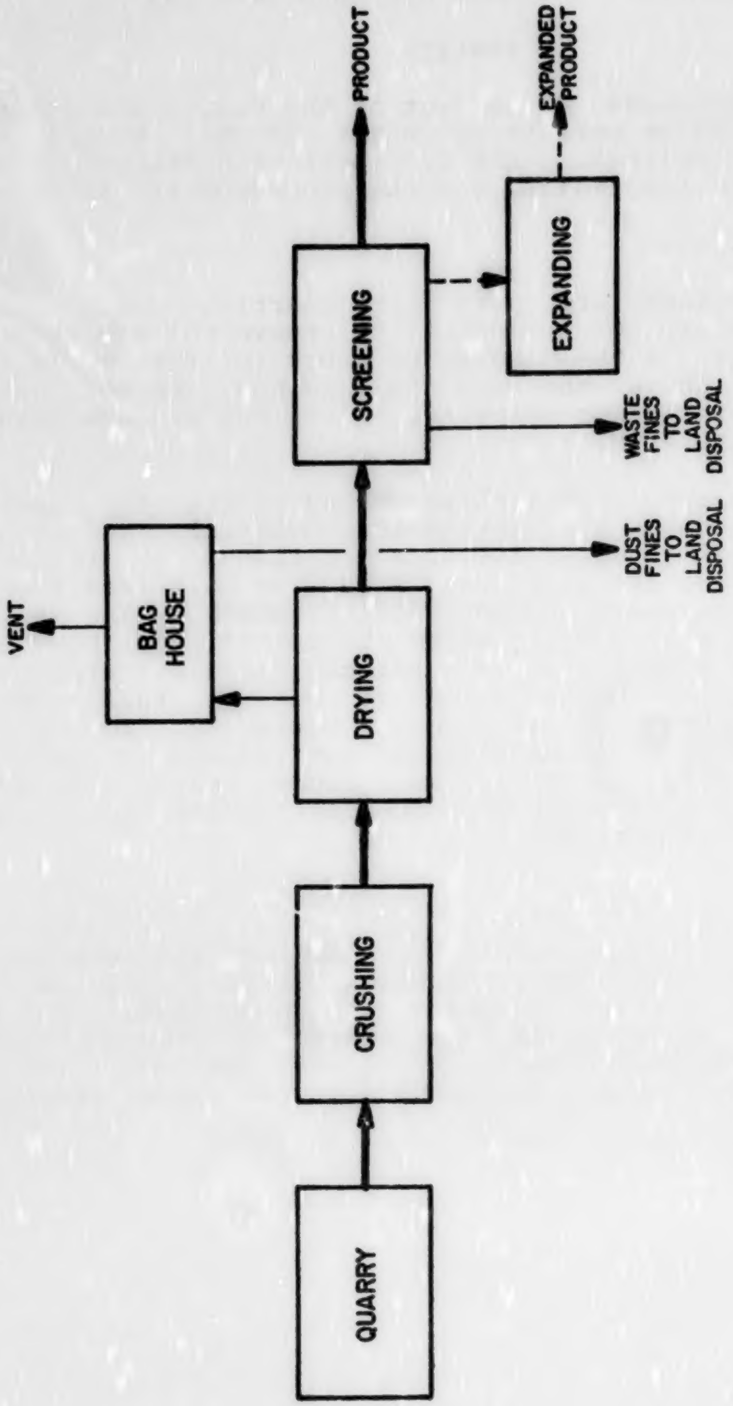


FIGURE 30
PERLITE MINING AND PROCESSING

Facility	Waste Material	kg/kkg product (lb/1000 lb)
5501	dust and fines	150-200
5502	large boulders fines	250
5503	large boulders fines	10 50

The wasted material represents approximately 10-25 percent loss of material in these mining and processing operations.

Water Use

There is currently no water used in the mining or processing operations. Facility 5500 does dewater the quarry when water accumulates, but this water is pumped out and evaporated on land.

Waste water Treatment

Since there is no water used, there is no waste water generated or water treatment required.

Effluent and Disposal

There are no effluents from these operations. The oversize materials, processing and baghouse fines are hauled to the mine areas and land-disposed. There is work being done by facilities 5501 and 5503 to reclaim further product grades from the waste fines. Facility 5501 is investigating the idea of a facility fines disposal process using water to make pellets designed to make land-disposal of fines easier and more efficient.

PUMICE

Process Description

Pumice is surface mined in open pit operations. The material is then crushed, screened, and shipped for use as either aggregate, cleaning powder or abrasive. A process flowsheet is given in Figure 31.

Raw Waste Load

At most facilities, there are no waterborne wastes as no water is employed. At some facilities, there are some solid wastes consisting of overburden and oversize materials (facility 5665 0.5 kg/kkg, facility 5669 37.5-151 kg/kkg). These are disposed of as landfill in mined out areas. Only one facility, facility 1705, has an effluent and this consists of waters from a wet scrubber used for dust control.

Water Use

At most operations, no water at all is employed. This is true for facilities 1702, 1703, 1704, 5665, 5667 and 5669. At facility 1701 a small amount of water (10.55 l/kkg product) is used for dust control purposes and this is absorbed by the product and not discharged. At facility 1705 a wet scrubber is used for dust control purposes.

Waste water Treatment

At all facilities except facility 1705, there is no waste water to be treated. At facility 1705, the scrubber water is discharged to a settling pond for removal of suspended materials prior to final discharge.

Effluent and Disposal

There is no effluent at any of the facilities except facility 1705. Facility 1705 operates on an intermittent basis, and no information is available on the composition of its discharge. This facility produces less than 0.1 percent of U.S. pumice.

VERMICULITE

Process Description

Mining of vermiculite at facility 5506 is conducted by bench quarrying using power shovels and loaders. Occasionally, blasting is necessary to break up irregularly occurring

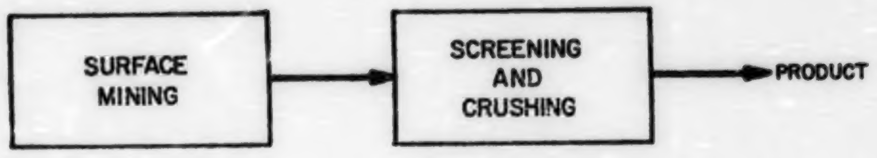


FIGURE 31
PUMICE MINING AND PROCESSING

dikes of syenite. Trucks then haul the ore to the process facility. The vermiculite is concentrated by a series of operations based on mechanical screening and flotation, a new process replacing one more dependent on mechanical separations. Sizer screens split the raw ore into coarse and fine fractions. The fines are washed, screened, and floated. After another screening the product is dewatered, dried and sent to the screening facility at another location.

The coarse fraction is re-screened and the fines from this screening are hydraulically classified. Coarse fractions from screening and classification are sent to a wet rod-processing operation and recycled. The coarsest fraction from the hydraulic classification is sent to coarse tails. The fines from hydraulic classification are screened, floated, re-screened and sent to join the other process stream at the dewatering stage.

Mining of vermiculite at facility 5507 is conducted by open pit mining using scrapers and bulldozers to strip off overburden. The ore is then hauled to the facility on dump trailer-tractor haul units. The overburden and sidewall waste is returned to the mine pit when it is reclaimed. The vermiculite ore is fed into the process facility where it is ground and deslimed. The vermiculite is then sent to flotation. After flotation, the product is dried, screened, and sent to storage for eventual shipping. Figure 32 is a flow diagram showing the mining and processing of vermiculite.

Raw Waste Loads

At facility 5506 waste is generated from the two thickening operations, from boiler water bleed, and from the washdown stream that is applied at the coarse tails-solids discharge point. (This is used to avoid pumping a wet slurry of highly abrasive pyroxenite coarse solids.)

At facility 5507, there is one waste stream coming from the mill generated from desliming, flotation and drying operations. This stream consists of mineral and earth solids, principally silicates including actinolite, feldspar, quartz, and minor amounts of tremolite, talc, and magnetite (1,600 kg/kkg product).

Water Use

Water comes from surface springs and runoff to facility 5507 vermiculite operations both as source and make-up water. At facility 5506, water from 2 local creeks provides both source and make-up water for the vermiculite operations. In

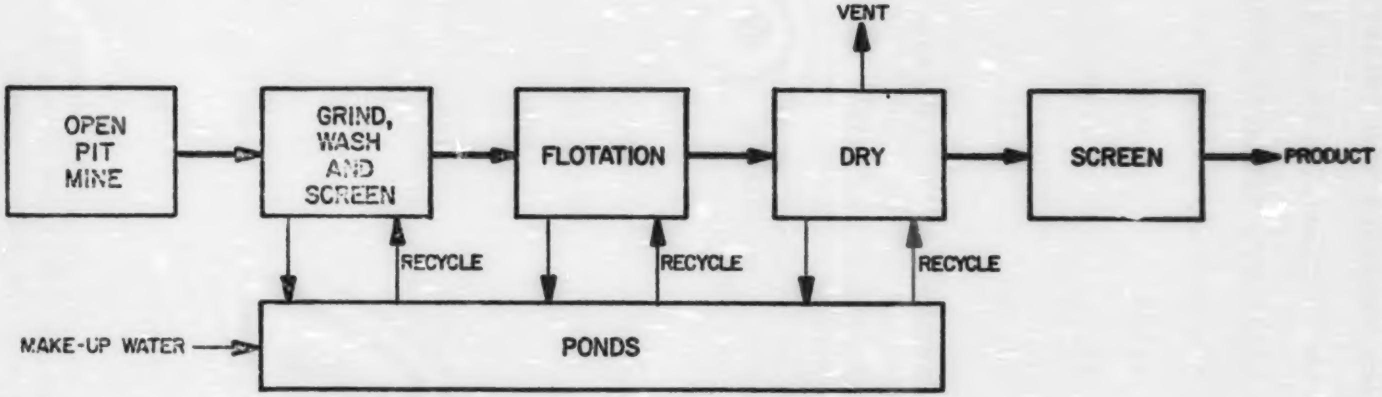


FIGURE 32
VERMICULITE MINING AND PROCESSING

dry weather a nearby river becomes the make-up water source. A well on the property provides sanitary and boiler water.

Consumption of water for the two facilities is as follows:

Facility	Consumption	l/kkg product	(gal/ton)
5507	process	46,400	(11,110)
	dust control	2,500	(600)
	evaporation from drying	83	(20)
	total consumed	48,900	(11,720)
	recycle	48,820	(11,700)
	net make-up water	83	(20)

Since the only water loss is through evaporation during drying operations and some unknown amount is lost through seepage from the ponds to ground water, the net amount of make-up water reflects this loss.

Facility	Consumption	l/kkg	(gal/ton)
5506	process	5,430	(1,580)
	boiler	120	(40)
	non-contact cooling	740	(220)
	total consumed	6,290	(1,840)
	recycle	4,820	(1,400)
	apparent water loss	1,480	(430)
	net make-up water	1,480	(430)

There is some water loss from the facility operation but no indication was given as to where the loss occurred, possibly boiler blowdown, product drying, or pond seepage.

Waste water Treatment

Both vermiculite operations have no discharge of waste waters. At facility 5506, the waste stream is pumped to a series of three settling ponds in which the solids are impounded, the water is clarified using aluminum sulfate as a flocculant, and the clear water is recycled to the process facility. The only water escape from this operation is due to evaporation and seepage from the pond into ground water. The overburden and sidewall waste is returned to the mine upon reclamation

At facility 5507, the waste streams are pumped to a tailings pond for settling of solids from which the clear water underflows by seepage to a "process facility pond" which serves as a reservoir for process water to the process facility. Local lumbering operations are capable of drastically altering water runoff in the watersheds around the mine. This requires by-pass streams around the ponding system.

Effluents and Disposal

Solid mineral wastes are land-disposed at both vermiculite operations. Both sites have no effluent as all water (excepting loss due to evaporation and seepage to ground water) is recycled to the process.

The recycled process water amounting to 10,200 l/min (2,700 gal/min) at facility 5507 has the following concentration of constituents (mg/l):

Acidity	6.48
Total solids	110
Total volatile solids	22
Alkalinity As $CaCO_3$	0
Hardness As $CaCO_3$	49.4
Fe	0.01
Mn	nil

MICA AND SERICITE (SIC 1499)

Mica and sericite are mined in open pits using conventional surface mining techniques. The crude ore from these mines is generally hauled to stockpiles at mills for processing.

Sixteen significant U.S. facilities producing flake, scrap or ground mica were identified in this study. Six of these facilities are dry grinding facilities processing either mica obtained from company-owned mines or purchased mica from an outside supplier, three facilities are wet grinding facilities and seven are wet mica beneficiation facilities utilizing froth flotation and/or spirals, hydroclassifiers and wet screening techniques to recover mica.

Additionally there are four known sericite producers in the U.S. Three of these companies surface mine the crude ore for brick facilities and a fourth company has a dry grinding facility and sells the sericite after processing.

DRY GRINDING OF MICA AND SERICITE

Dry grinding facilities are of two types, those which process ore obtained directly from the mine and others which process beneficiated scrap and flake mica. A generalized flow diagram for these facilities are given in Figure 33.

The ore from the mine is processed through coarse and fine screens before processing. The wastes generated from the two screening operations consist of rocks, boulders, etc., which are bulldozed into stockpiles. The crude ore is next fragmented, dried and sent to a hammerprocess facility. In those facilities which process scrap and flake mica, the feed is sent directly into the hammerprocess facility or into a pulverizer. In both types of facilities, the milled product is passed through a series of vibrating screens to separate various sizes of product for bagging. The waste material from the screening operations consists of quartz and schist pebbles.

In some facilities either the screened ore or the scrap and flake mica is processed in a fluid energy process facility. The ground product, in these facilities, is next classified in a closed circuit air classifier to yield various grades of products. Dry grinding facilities utilize baghouse collectors for air pollution control. The dust is reclaimed from these collectors and marketed. Process water is not used in dry grinding facilities, therefore, during normal operating conditions, waterborne pollutants are not generated by these facilities.

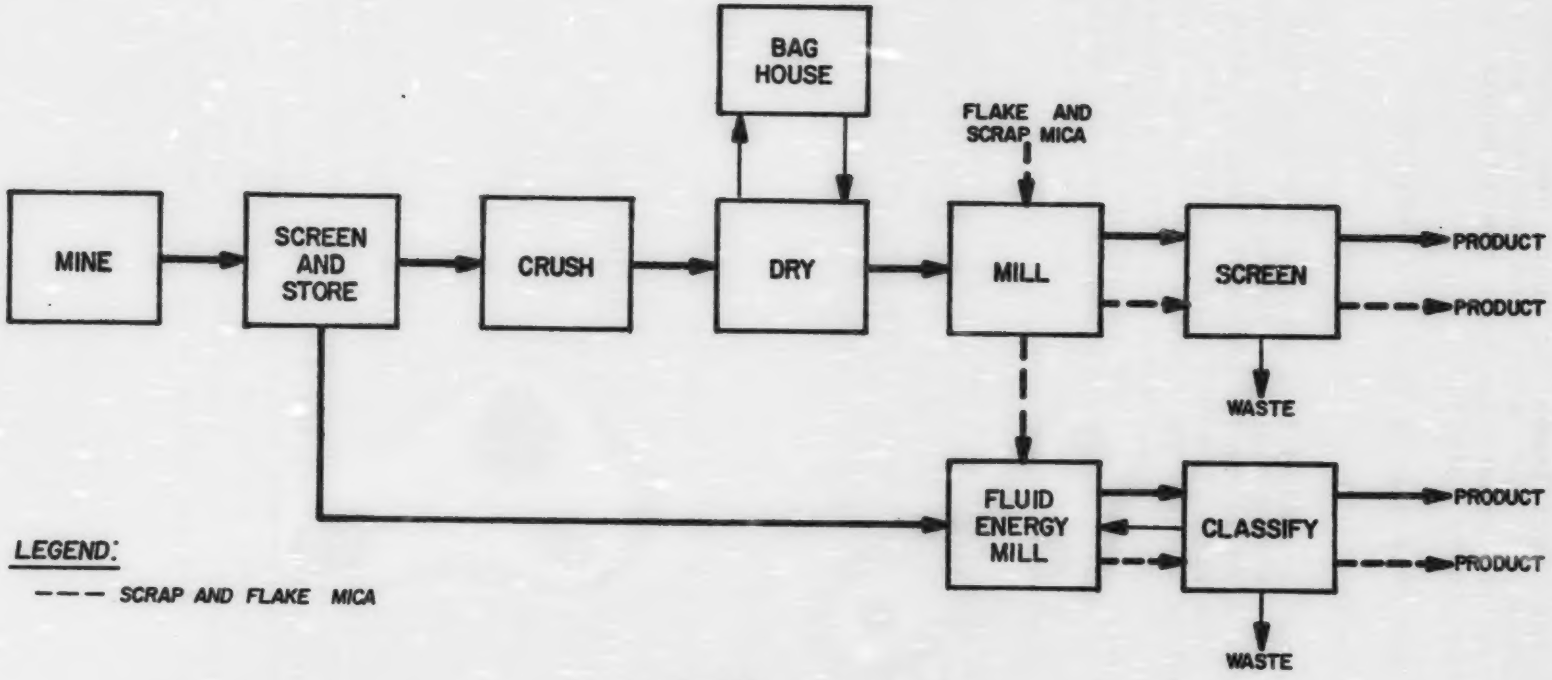


FIGURE 33
MICA MINING AND PROCESSING
(DRY)

Even though these facilities do not use process water, natural drainage at the mine and process facility could carry fines from the stockpiles to a considerable distance, during and after heavy rainfall.

WET GRINDING OF MICA AND SERICITE

Process Description

In a typical wet grinding facility, scrap and flake mica is batch milled in a water slurry. The mica rich concentrate from the process facility is decanted, dried, screened, and then bagged. The mica product from these facilities is primarily used by the paint, rubber, and plastic industries. The tailings from the process facility are dewatered to remove the sand. The effluents emanating from the decanting and dewatering operations constitute the waste stream from the facility. A generalized flow diagram for wet grinding operations is shown in Figure 34.

At one facility visited the scrap and flake mica is processed in a fluid energy process facility using steam. The steam generated in boilers is used in process and vented to the atmosphere. The waste streams emanating from the boiler operations are sludge generated from the conventional water softening process, filter backwash, and boiler blowdown wastes.

Raw Waste Loads

The raw waste loads for facilities 2055 and 2059 are given below:

	kg/kkg of product (lb/1000 lb)	
	2055	2059
clays and sands	100	50

Water Use

Facilities 2059 and 2055 consume water at 4,900 and 12,500 l/kkg product (1,300 and 3,000 gal/ton), respectively. At facility 2055, about 80 percent of the water used in the process is make-up water, the remainder is recycled water from the decanting and dewatering operations. At facility 2059 makeup water consumed is 1,500 l/kkg of product (360 gallons/ton); the remainder is recycled from the settling pond. The hydraulic loads of these facilities are given below:

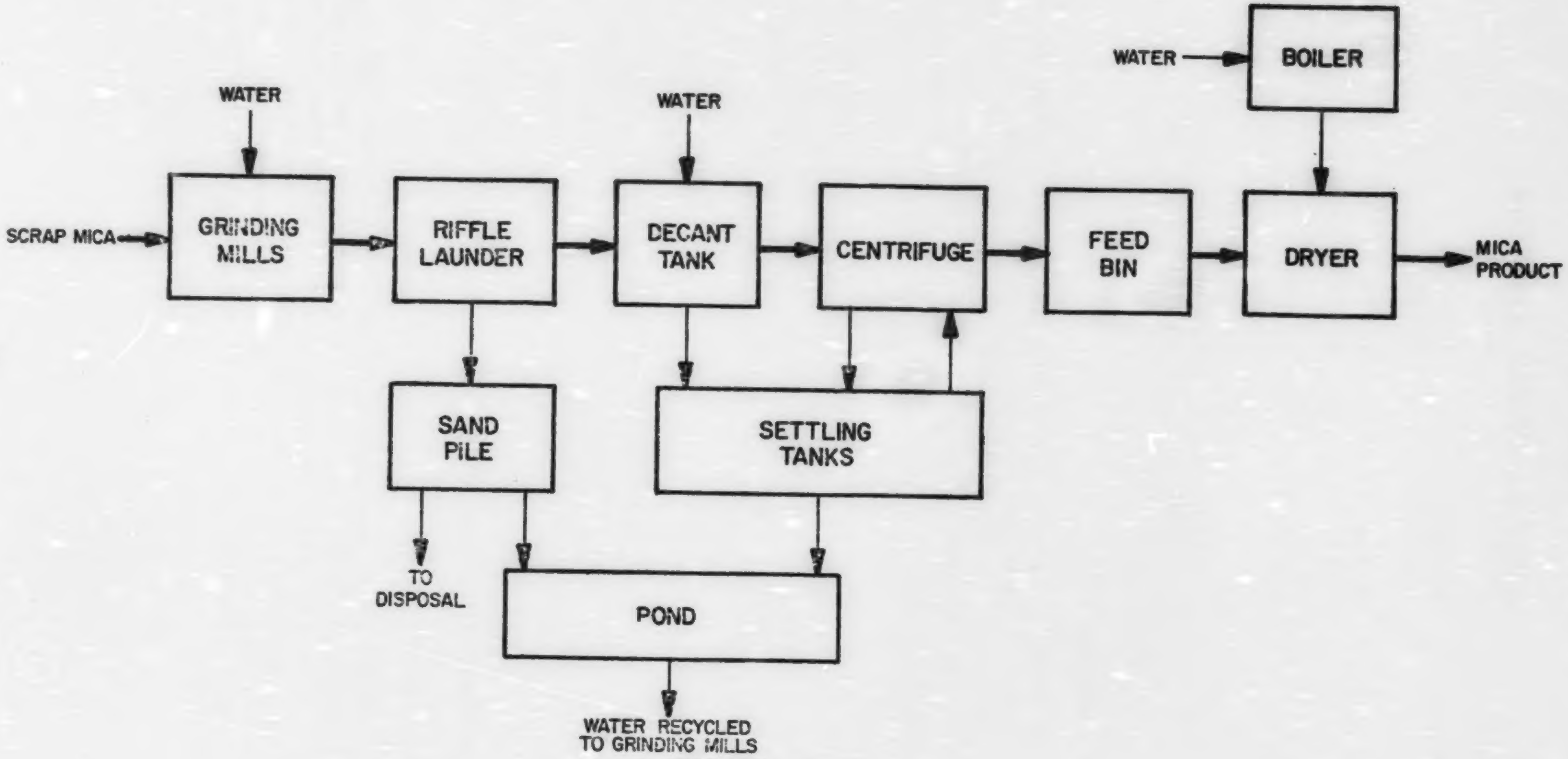


FIGURE 34
MICA MINING AND PROCESSING
(WET)

	l/kkg of product (gal/ton)	
	2055	2059
Make-up water	10,000 (2,400)	2,200 (530)
Recycled water	2,500 (600)	4,200 (1,000)
Boiler feed	unknown	1,100 (260)
Total Process Water	12,500 (3,000)	5,400 (1,300)

Waste Treatment

At facility 2055, the raw waste stream is collected in surge tanks and about 20 percent of the decanted water is recycled to the process. The remainder is pumped to a nearby facility for treatment. The treatment consists of adding polymer, clarification and filtration. The filter cake is stockpiled and the filtrate discharged.

At facility 2059, the waste stream flows to settling tanks. The underflow from the settling tanks is sent back to the process for mica recovery. The overflow goes into a 0.8 hectare (2 acre) pond for settling. The decanted water from this pond is recycled to the process.

Effluent Composition

The effluent from facility 2055 is treated and discharged by a neighboring company. Facility 2059 has no discharge under normal operating conditions. However, during heavy rainfall, the settling pond overflows and the effluent is discharged.

WET BENEFICIATION PROCESS OF MICA AND SERICITE

Process Description

These ores contain approximately 5 to 15 percent mica. At the beneficiation facility, the soft weathered material from the stockpiles is hydraulically sluiced into the processing units. The recovery of mica from the ore requires two major steps, first, the coarse flakes are recovered by spirals and/or trommel screens and second, fine mica is recovered by froth flotation.

Five of the seven facilities discussed below use a combination of spiral classifiers and flotation techniques and the remaining two facilities use only spirals to recover the mica from the crude ore. Beneficiation includes crushing, screening, classification, and processing. The larger mica flakes are then separated from the waste sands in spiral classifiers. The fine sand and clays are deslimed, conditioned and sent to the flotation section for mica recovery. In facilities using only spirals, the underflow is screened to recover flaked mica. In both types of facilities, the mica concentrate or the flake mica is centrifuged, dried, and ground.

Although all flotation facilities use the same general processing steps, in some facilities, tailings are processed to recover additional by-products. Facility 2050 processes the classifier waste stream to produce clays for use by the brick industry and also processes the mica flotation tailings to recover feldspar. Facilities 2052 and 2057 process the classifier waste to recover a high grade clay for use by the ceramic industry. Generalized flow diagrams for facilities using a combination of spirals and flotation and for facilities using spirals only is given in Figure 35.

Raw Waste Loads

The raw waste load in these facilities consists of mill tailings, thickener overflow, and wastes from the various dewatering units. In some facilities, waste water from wet scrubbing operations is used for dust control purposes. The raw waste loads for these facilities are given as follows:

Facility	Clay, slimes, mica fines and sand wastes kg/kkg of product (lb/1000 lb)
2050	600
2051	14,400
2052	2,600
2053	4,000
2054	4,700
2057	2,900
2058	6,300

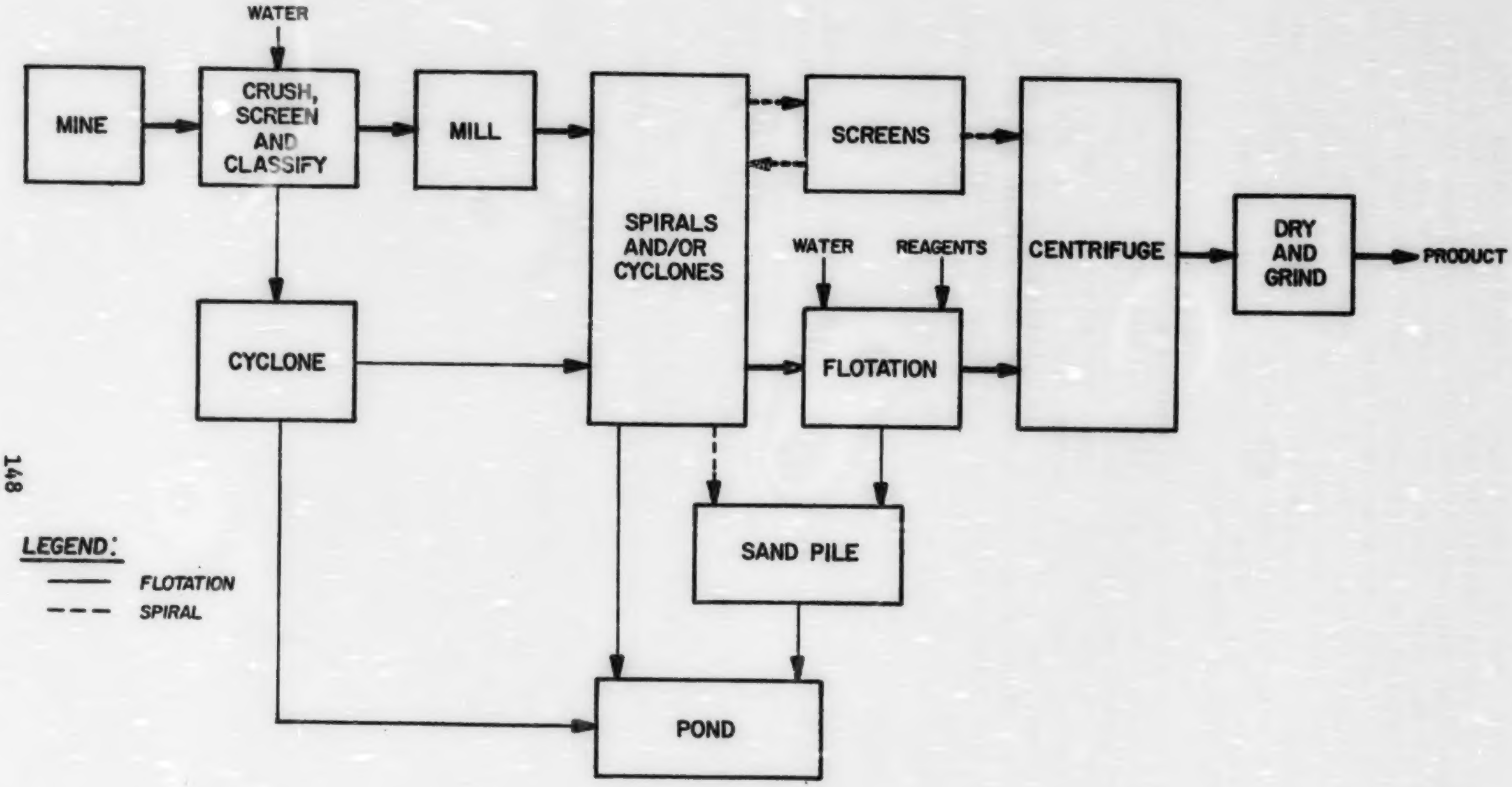


FIGURE 35
MICA MINING AND PROCESSING
(FLOTATION OR SPIRAL SEPARATION)

Water Use

The water used in these facilities is dependent upon the quantity and type of clay material in the crude ore. These facilities consume water at 69,500 to 656,000 l/kkg (16,700 to 157,000 gal/ton) of product. The hydraulic loads of these facilities are summarized as follows:

Facility	Process Water Used l/kkg of product	(gal/ton)
2050	95,200	(22,800)
2051	240,000	(57,600)
2052	125,000	(30,000)
2053	110,000	(26,400)
2054	69,500	(16,700)
2057	143,000	(34,000)
2058	656,000	(157,000)

Facility	Other Water Consumption l/kkg of product (gal/ton) process discharge	loss due evaporation, percolation and spills
2050	none	negligible
2051	none	negligible
2052	75,200 (18,000)	50,600 (12,100)
2053	none	80 (20)
2054	69,500 (16,700)	-------
2057	86,000 (20,600)	57,000 (13,700)
2058	none	-------

Waste Treatment

In facilities 2050, 2051, 2053, and 2058, the wastes are treated by settling in ponds and the supernatant from the last pond is recycled to the facility. The sizes of the ponds used at each facility are given below.

Facility	hectares	(acres)
2050	7.3	(18)
2051	3.2	(8)
2053	0.8, 1.6, 2.8	(2, 4, 7)
2058	8.1	(20)

During normal operating procedures, there is no discharge from ponds 2050 and 2051. However, these ponds discharge during exceptionally heavy rainfalls (4" rain/24 hours). The only discharge at facility 2058 is the drainage from the sand stockpiles which flows into a 0.4 hectare (1-acre) pond which discharges.

At facility 2054 waste water is treated in a 1.2 hectare (3-acre) pond. The effluent from this pond is discharged. This facility has suspended its operation since June, 1974, due to necessary repairs to the pond, and plans to convert the water flow system of this operation to a closed circuit "no discharge" process by the addition of thickening and filtration equipment.

At facilities 2052 and 2057 the waste water is treated in a series of ponds and the overflow from the last pond is treated by lime for pH adjustment prior to discharge. Facility 2052 has three ponds of 1.2, 1.6, and 3.6 hectares (3, 4, and 9 acres, respectively) in size. In addition to mica, these two facilities produce clay for use by ceramic industries. According to responsible company officials, these two facilities cannot operate on a total water recycle basis. The amine reagent used in flotation circuits is detrimental to the clay products as it affects their viscosity and plasticity.

Effluent Composition

The significant constituents in the effluent from these facilities are given below:

facility	2052	2054	2057
pH before lime treatment	4.2	---	4.3
pH after lime treatment	6.5	6 - 9	6.5
TSS, mg/l	20	400	<15
settleable solids, ml/liter	<0.1	<0.1	<0.1

There is no quantitative data available on the discharge from facility 2058.

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

INTRODUCTION

The waste water constituents of pollution significance for this segment of the mineral mining and processing industry are based upon those parameters which have been identified in the untreated wastes from each subcategory of this study. The waste water constituents are further divided into those that have been selected as pollutants of significance with the rationale for their selection, and those that are not deemed significant with the rationale for their rejection.

The basis for selection of the significant pollutant parameters was:

(1) toxicity to terrestrial and aquatic organisms;
(2) substances causing dissolved oxygen depletion in streams;
(3) soluble constituents that result in undesirable tastes and odors in water supplies;
(4) substances that result in eutrophication and stimulate undesirable algal growth;
(5) substances that produce unsightly conditions in receiving water; and
(6) substances that result in sludge deposits in streams.

SIGNIFICANCE AND RATIONALE FOR SELECTION OF POLLUTION PARAMETERS

Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand (BOD) is a measure of the oxygen consuming capabilities of organic matter. The BOD does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a BOD, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high BOD indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and less able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD can kill all inhabitants of the affected area.

If a high BOD is present, the quality of the water is usually visually degraded by the presence of decomposing materials and alga blooms due to the uptake of degraded materials that form the food stuffs of the algal populations. BOD was not a major contribution to pollution in this industry, but may possibly exist because of the use of organic flotation agents.

Fluorides

As the most reactive non-metal, fluorine is never found free in nature but as a constituent of fluorite or fluorspar, calcium fluoride, in sedimentary rocks and also of cryolite, sodium aluminum fluoride, in igneous rocks. Owing to their origin only in certain types of rocks and only in a few regions, fluorides in high concentrations are not a common constituent of natural surface waters, but they may occur in detrimental concentrations in ground waters.

Fluorides are used as insecticides, for disinfecting brewery apparatus, as a flux in the manufacture of steel, for preserving wood and mucilages, for the manufacture of glass and enamels, in chemical industries, for water treatment, and for other uses.

Fluorides in sufficient quantity are toxic to humans, with doses of 250 to 450 mg giving severe symptoms or causing death.

There are numerous articles describing the effects of fluoride-bearing waters on dental enamel of children; these studies lead to the generalization that water containing less than 0.9 to 1.0 mg/l of fluoride will seldom cause mottled enamel in children, and for adults, concentrations less than 3 or 4 mg/l are not likely to cause endemic cumulative fluorosis and skeletal effects. Abundant literature is also available describing the advantages of maintaining 0.8 to 1.5 mg/l of fluoride ion in drinking water to aid in the reduction of dental decay, especially among children.

Chronic fluoride poisoning of livestock has been observed in areas where water contained 10 to 15 mg/l fluoride. Concentrations of 30-50 mg/l of fluoride in the total ration of dairy cows is considered the upper safe limit. Fluoride from waters apparently does not accumulate in soft tissue to a significant degree and it is transferred to a very small extent into the milk and to a somewhat greater degree into eggs. Data for fresh water indicate that fluorides are toxic to fish at concentrations higher than 1.5 mg/l. Fluoride is found in one industry subcategory in this segment, the mining and processing of industrial sand by the HF flotation process.

Iron

Iron is considered to be a highly objectionable constituent in public water supplies, the permissible criterion has been set at 0.3 mg/l.

Oil and Grease

Oil and grease exhibit an oxygen demand. Oil emulsions may adhere to the gills of fish or coat and destroy algae or other plankton. Deposition of oil in the bottom sediments can serve to inhibit normal benthic growths, thus interrupting the aquatic food chain. Soluble and emulsified material ingested by fish may taint the flavor of the fish flesh. Water soluble components may exert toxic action on fish. Floating oil may reduce the re-aeration of the water surface and in conjunction with emulsified oil may interfere with photosynthesis. Water insoluble components damage the plumage and coats of aquatic animals and fowls. Oil and grease in the water can result in the formation of objectionable surface slicks preventing the full aesthetic enjoyment of the water. Oil spills can damage the surface of boats and can destroy the aesthetic characteristics of beaches and shorelines.

Acidity and Alkalinity

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity and alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousandfold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer. Appreciable irritation will cause severe pain.

Total Suspended Solids

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for most industrial processes and power facilities. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic facilities.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat. When of an organic and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a seemingly inexhaustible food source for sludgeworms and associated organisms.

Turbidity is principally a measure of the light absorbing properties of suspended solids. It is frequently used as a substitute method of quickly estimating the total suspended solids when the concentration is relatively low. Total suspended solids are the single most important pollutant parameter found in this segment of the mineral mining and processing industry.

Asbestos

"Asbestos" is a generic term for a number of fire-resistant hydrated silicates that, when crushed or processed, separate into flexible fibers made up of fibrils noted for their great tensile strength. Although there are many asbestos minerals, only five are of commercial importance: chrysotile, a tubular serpentine mineral, accounts for 95 percent of the world's production; the others, all amphiboles, are amosite, crocidolite, anthophyllite, and tremolite. The asbestos minerals differ in their metallic elemental content, range of fiber diameters, flexibility or hardness, tensile strength, surface properties, and other attributes that determine their industrial uses and may affect their respirability, deposition, retention, translocation, and biologic reactivity.

Serpentine asbestos is a magnesium silicate the fibers of which are strong and flexible so that spinning is possible with the longer fibers. Amphibole asbestos includes various silicates of magnesium, iron, calcium, and sodium. The fibers are generally brittle and cannot be spun but are more resistant to chemicals and to heat than serpentine asbestos.

Chrysoltile	$3MgO \bullet 2SiO_2 \bullet 2H_2O$
Anthophyllite	$(FeMg) \bullet SiO_3 \bullet H_2O$
Amosite	(ferroanthophyllite)
Crocidolite	$NaFe \bullet (SiO_3)_2 \bullet FeSiO_3 \bullet H_2O$
Tremolite	$Ca_2Mg_5Si_8O_{22}(OH)_2$

All epidemiologic studies that appear to indicate differences in pathogenicity among types of asbestos are flawed by their lack of quantitative data on cumulative exposures, fiber characteristics, and the presence of cofactors. The different types, therefore, cannot be graded as to relative risk with respect to asbestosis. Fiber size is critically important in determining respirability, deposition, retention, and clearance from the pulmonary tract and is probably an important determinant of the site and nature of biologic action. Little is known about the movement of the fibers within the human body, including their potential for entry through the gastrointestinal tract. There is evidence though that bundles of fibrils may be broken down within the body to individual fibrils.

SIGNIFICANCE AND RATIONALE FOR REJECTION OF POLLUTION PARAMETERS

A number of pollution parameters besides those selected were considered, but had to be rejected for one or several of the following reasons:

(1) insufficient data on facility effluents;
(2) not usually present in quantities sufficient to cause water quality degradation;
(3) treatment does not "practicably" reduce the parameter; and
(4) simultaneous reduction is achieved with another parameter which is limited.

Toxic Materials

Although arsenic, antimony, barium, boron, cadmium, chromium, copper, cyanide ion, manganese, mercury, nickel, lead, selenium, tin, and zinc are harmful pollutants, they were not found to be present in quantities sufficient to cause water quality degradation.

Dissolved Solids

The total dissolved solids is a gross measure of the amount of soluble pollutants in the waste water. It is an important parameter in drinking water supplies and water used for irrigation. A total dissolved solids content of less than 500 mg/l is considered desirable. From the standpoint of quantity discharged, TDS could have been considered a harmful characteristic. However, energy requirements, especially for evaporation, and solid waste disposal costs are usually so high as to preclude limiting dissolved solids at this time. The cations Al^{+3}, Ca^{+2}, Mg^{+2}, K^{+} and Na^{+}, the anion Cl^{-} and the radical groups CO_3^{-2}, NO_2^{-}, phosphates and silicates are commonly found in all nautral water bodies. Process water, mine water and storm runoff will accumulate quantities of the above constutuents both in the form of suspended and dissolved solids. However, their amount is small and certainly not enough to cause water quality problems. Limiting suspended solids and dissolved solids, where they pose a problem, is a more practicable approach to limiting these ions.

Temperature

Temperature is one of the most important and influential water quality characteristics. Temperature determines those species that may be present; it activates the hatching of young, regulates their activity, and stimulates or suppresses their growth and development; it attracts, and may kill when the water becomes too hot or becomes chilled too suddenly. Colder water generally suppresses development. Warmer water generally accelerates activity and may be a primary cause of aquatic facility nuisances when other environmental factors are suitable.

Temperature is a prime regulator of natural processes within the water environment. It governs physiological functions in organisms and, acting directly or indirectly in combination with other water quality constituents, it affects aquatic life with each change. These effects include chemical reaction rates, enzymatic functions, molecular movements, and molecular exchanges between membranes within and between the physiological systems and the organs of an animal.

Chemical reaction rates vary with temperature and generally increase as the temperature is increased. The solubility of gases in water varies with temperature. Dissolved oxygen is decreased by the decay or decomposition of dissolved organic substances and the decay rate increases as the temperature of the water increases reaching a maximum at about 30°C (86°F). The temperature of stream water, even during summer, is below the optimum for pollution-associated bacteria. Increasing the water temperature increases the bacterial multiplication rate when the environment is favorable and the food supply is abundant.

Reproduction cycles may be changed significantly by increased temperature because this function takes place under restricted temperature ranges. Spawning may not occur at all because temperatures are too high. Thus, a fish population may exist in a heated area only by continued immigration. Disregarding the decreased reproductive potential, water temperatures need not reach lethal levels to decimate a species. Temperatures that favor competitors, predators, parasites, and disease can destroy a species at levels far below those that are lethal.

Fish food organisms are altered severely when temperatures approach or exceed 90°F. Predominant algal species change, primary production is decreased, and bottom associated organisms may be depleted or altered drastically in numbers and distribution. Increased water temperatures may cause aquatic facility nuisances when other environmental factors are favorable.

Synergistic actions of pollutants are more severe at higher water temperatures. Given amounts of domestic sewage, refinery wastes, oils, tars, insecticides, detergents, and fertilizers more rapidly deplete oxygen in water at higher temperatures, and the respective toxicities are likewise increased.

When water temperatures increase, the predominant algal species may change from diatoms to green algae, and finally at high temperatures to blue-green algae, because of species temperature preferentials. Blue-green algae can cause serious odor problems. The number and distribution of benthic organisms decreases as water temperatures increase above 90°F, which is close to the tolerance limit for the population. This could seriously affect certain fish that depend on benthic organisms as a food source.

The cost of fish being attracted to heated water in winter months may be considerable, due to fish mortalities that may result when the fish return to the cooler water.

Rising temperatures stimulate the decomposition of sludge, formation of sludge gas, multiplication of saprophytic bacteria and fungi (particularly in the presence of organic wastes), and the consumption of oxygen by putrefactive processes, thus affecting the esthetic value of a water course.

In general, marine water temperatures do not change as rapidly or range as widely as those of freshwaters. Marine and estuarine fishes, therefore, are less tolerant of temperature variation. Although this limited tolerance is greater in estuarine than in open water marine species, temperature changes are more important to those fishes in estuaries and bays than to those in open marine areas, because of the nursery and replenishment functions of the estuary that can be adversely affected by extreme temperature changes.

Excess thermal load, even in non-contact cooling water, has not been and is not expected to be a significant problem in this segment of the mineral mining and processing industry.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

INTRODUCTION

Waterborne wastes from the mining of minerals for the construction industry consist primarily of suspended solids. These are usually composed of chemically inert and very insoluble sand, clay or rock particles. Treatment technology is well developed for removing such particles from waste water and is readily applicable whenever space requirements or economics do not preclude utilization.

In a few instances dissolved substances such as fluorides, acids, alkalies, and chemical additives from ore processing may also be involved. Where they are present, dissolved material concentrations are usually low. Treatment technology for the dissolved solids is also well-known, but may often be limited by the large volumes of waste water involved and the cost of such large scale operations.

The control and treatment of the usually simple waterborne wastes found in the mining and processing of minerals for the construction industry are complicated by several factors:

(1) the large volumes of waste water involved for many of the processing operations,

(2) variable waste water amount and composition from day to day, as influenced by rainfall and other surface and underground water contributions,

(3) differences in waste water compositions arising from ore or raw material variability,

(4) geographical location: e.g., waste water can be handled differently in dry isolated locations than in industrialized wet climates.

Each of these points are discussed in the following sections.

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PROBLEM POLLUTANTS

Two significant waste water problem areas have been found in this industry:

(1) High suspended solids levels in discharged waste water resulting from submicron suspensions which are difficult to settle. This problem is encountered in several segments of this industry.

(2) In at least one subcategory of this industry problems are encountered with waterborne fluoride wastes.

Suspended solids come from mine drainage, rainwater runoff, air pollution scrubber water, and process water. Massive quantities of process water are used in the sand and gravel, crushed stone, industrial sand, and mica industries. Much of this process water, used for classifying and beneficiating operations may be recycled with relatively high suspended solids concentrations, often 200 mg/l. This makes recycling process water not only feasible but also economical since treatment facility demands are not as great for water of this quality. However, in some cases, where flotation is employed, sensitivity of the process to the flotation reagents added makes complete recycle of process water unfeasible, giving rise to effluents. This occurs in some industrial sand and mica operations.

In other operations which use no process water or whose process water volume is small, scrubber water, mine drainage, and rainwater runoff are the major sources of suspended solids. Dimension stone, gypsum, asbestos, and gilsonite are examples of such industries. Asbestos presents a special suspended solids problem in its mine drainage due to the presence of asbestos fibers.

One of the industrial sand subcategories uses a process employing hydrofluoric acid as a flotation reagent. This gives rise to an acidic fluoride bearing waste water stream which must be treated.

CONTROL PRACTICES

Control practices such as selection of raw materials, good housekeeping, minimizing leaks and spills, in-process changes, and segregation of process waste water streams are not as important in the mining of minerals for the construction industry as they are in more process-oriented manufacturing operations. Raw materials are fixed by the composition of the ore available; good housekeeping and small leaks and spills have little influence on the waste loads; and it is rare that any noncontact water, such as cooling water, is involved in minerals mining and processing.

There are a number of areas, however, where control is very important. These include:

(1) waste water containment

(2) separation and control of mine water, process water, and rain water

(3) monitoring of waste streams.

Containment

The majority of waste water treatment and control facilities in the mining of minerals for the construction industry use one or more settling ponds. Often the word "pond" is an euphemism for swamp, gully, or other low spot which will collect water. In times of heavy rainfall these "ponds" are often flooded and the settled solids may be swept along as well. In many other cases, the identity of the pond may be maintained during rainfall but its function as a settling pond is significantly impaired by the large amount of water flowing through it. In addition to rainfall and flooding conditions, waste containment in ponds can be troubled with seepage through the ground around and beneath the pond, escape through pot holes, faults and fissures below the water surface and physical failure of pond dams and dikes.

In most instances satisfactory pond performance can be achieved by proper design. In instances where it is not possible to achieve satisfactory pond performance, alternative treatment methods can be utilized: thickeners, clarifiers, tube and lamella separators, filters, hydrocyclones, and centrifuges.

Separation and Control of Waste water

In these industries waste water may be separated into different categories:

(1) Mine drainage water. Since minerals mining operations often involve large surface areas, the rain water that falls on the mine or mine property surface constitutes a major portion of the overall waste water load leaving the property. This runoff entrains minerals, silt, sand, clay, organic matter and other suspended solids.

(2) Process water. This is water involved in transporting, classifying, washing, beneficiating, and separating ores and other mined materials. When present in minerals

mining operations this water usually contains heavy loads of suspended solids and possibly some dissolved materials.

The relative amounts and compositions of the above waste water streams differ from one mining category to another and the separation, control and treatment techniques differ for each.

Process water is normally controlled and contained by pumping or gravity flow through pipes, channels, ditches and ponds. Mine drainage, on the other hand, is often uncontrolled and may either contaminate process and mine drainage water or flow off the land independently as non-point discharges. Mine drainage also increases suspended solid material in rivers, streams, creeks or other surface water used for process water supply or, in some cases, as point discharge sources from mining property.

Control technology, as discussed in this report, includes techniques and practices employed before, during, and after the actual mining or processing operation to reduce or eliminate adverse environmental effects resulting from the discharge of mine or process facility waste water. Effective pollution-control planning can reduce pollutant contributions from active mining and processing sites and can also minimize post-operational pollution potential. Because pollution potential may not cease with closure of a mine or process facility, control measures also refer to methods practiced after an operation has terminated production of ore or concentrated product. The presence of pits, storage areas for spoil (non-ore material, or waste), tailing ponds, disturbed areas, and other results or effects of mining or processing operations necessitates integrated plans for reclamation, stabilization, and control to return the affected areas to a condition at least fully capable of supporting the uses which it was capable of supporting prior to any mining and to achieve a stability not posing any threat of water diminution, or pollution and to minimize potential hazards associated with closed operations.

Mining Techniques

Mining techniques can effectively reduce amounts of pollutants coming from a mine area by containment within the mine area or by reducing their formation. These techniques can be combined with careful reclamation planning and implementation to provide maximum at-source pollution control.

Several techniques have been implemented to reduce environmental degradation during strip-mining operations.

Utilization of the box-cut technique in moderate- and shallow-slope contour mining has increased recently because more stringent environmental controls are being implemented.

A box cut is simply a contour strip mine in which a low-wall barrier is maintained. Spoil may be piled on the low wall side. This technique significantly reduces the amount of water discharged from a pit area, since that water is prevented from seeping through spoil banks. The problems of preventing slides, spoil erosion, and resulting stream sedimentation are still present, however.

Block-cut mining was developed to facilitate regrading, minimize overburden handling, and contain spoil within mining areas. In block-cut mining, contour stripping is typically accomplished by throwing spoil from the bench onto downslope areas. This downslope material can slump or rapidly erode and must be moved upslope to the mine site if contour regrading is desired. The land area affected by contour strip mining is substantially larger than the area from which the ores are extracted. When using block-cut mining, only material from the first cut is deposited in adjacent low areas. Remaining spoil is then placed in mined portions of the bench. Spoil handling is restricted to the actual pit area for all areas but the first cut, which significantly reduces the area disturbed.

Pollution-control technology in underground mining is largely restricted to at-source methods of reducing water influx into mine workings. Infiltration from strata surrounding the workings is the primary source of water, and this water reacts with air and sulfide minerals within the mines to create acid pH conditions and, thus, to increase the potential for solubilization of metals. Underground mines are, therefore, faced with problems of water handling and mine-drainage treatment. Open-pit mines, on the other hand, receive both direct rainfall and runoff contributions, as well as infiltrated water from intercepted strata.

Infiltration in underground mines generally results from rainfall recharge of a ground-water reservoir. Rock fracture zones, joints, and faults have a strong influence on ground-water flow patterns since they can collect and convey large volumes of water. These zones and faults can intersect any portion of an underground mine and permit easy access of ground water. In some mines, infiltration can result in huge volumes of water that must be handled and treated. Pumping can be a major part of the mining operation in terms of equipment and expense--particularly, in mines which do not discharge by gravity.

Water-infiltration control techniques, designed to reduce the amount of water entering the workings, are extremely important in underground mines located in or adjacent to water-bearing strata. These techniques are often employed in such mines to decrease the volume of water requiring handling and treatment, to make the mine workable, and to control energy costs associated with dewatering. The techniques include pressure grouting of fissures which are entry points for water into the mine. New polymer-based grouting materials have been developed which should improve the effectiveness of such grouting procedures. In severe cases, pilot holes can be drilled ahead of actual mining areas to determine if excessive water is likely to be encountered. When water is encountered, a small pilot hole can be easily filled by pressure grouting, and mining activity may be directed toward non-water-contributing areas in the formation. The feasibility of such control is a function of the structure of the ore body, the type of surrounding rock, and the characteristics of ground water in the area.

Decreased water volume, however, does not necessarily mean that waste water pollutant loading will also decrease. In underground mines, oxygen, in the presence of humidity, interacts with minerals on the mine walls and floor to permit pollutant formation e.g., acid mine water, while water flowing through the mine transports pollutants to the outside. If the volume of this water is decreased but the volume of pollutants remains unchanged, the resultant smaller discharge will contain increased pollutant concentrations, but approximately the same pollutant load. Rapid pumpout of the mine can, however, reduce the contact time and significantly reduce the formation of pollutants.

Reduction of mine discharge volume can reduce water handling costs. In cases of acid mine drainage, for example, the same amounts of neutralizing agents will be required because pollutant loads will remain unchanged. The volume of mine water to be treated, however, will be reduced significantly, together with the size of the necessary treatment and settling facilities. This cost reduction, along with cost savings which can be attributed to decreased pumping volumes (hence, smaller pumps, lower energy requirements, and smaller treatment facilities), makes use of water infiltration-control techniques highly desirable.

Water entering underground mines may pass vertically through the mine roof from rock formation above. These rock units may have well-developed joint systems (fractures along which no movement occurs), which tend to facilitate vertical flow. Roof collapses can also cause widespread fracturing in overlying rocks, as well as joint separation far above the mine roof. Opened joints may channel flow from overlying aquifers (water-bearing rocks), a flooded mine above, or even from the surface.

Fracturing of overlying strata is reduced by employing any or all of several methods: (1) Increasing pillar size; (2) Increasing support of the roof; (3) Limiting the number of mine entries and reducing mine entry widths; (4) Backfilling of the mined areas with waste material.

Surface mines are often responsible for collecting and conveying large quantities of surface water to adjacent or underlying underground mines. Ungraded surface mines often collect water in open pits when no surface discharge point is available. That water may subsequently enter the ground-water system and then percolate into an underground mine. The influx of water to underground mines from either active or abandoned surface mines can be significantly reduced through implementation of a well-designed reclamation plan.

The only actual underground mining technique developed specifically for pollution control is preplanned flooding. This technique is primarily one of mine design, in which a mine is planned from its inception for post-operation flooding or zero discharge. In drift mines and shallow slope or shaft mines, this is generally achieved by working the mine with the dip of the rock (inclination of the rock to the horizontal) and pumping out the water which collects in the shafts. Upon completion of mining activities, the mine is allowed to flood naturally, eliminating the possibility of acid formation caused by the contact between sulfide minerals and oxygen. Discharges, if any, from a flooded mine should contain a much lower pollutant concentration. A flooded mine may also be sealed.

Surface-Water Control

Pollution-control technology related to mining areas, ore beneficiation facilites, and waste-disposal sites is generally designed for prevention of pollution of surface waters (i.e., streams, impoundments, and surface runoff). Prior planning for waste disposal is a prime control method. Disposal sites should be isolated from surface flows and impoundments to prevent or minimize pollution potential. In addition, several techniques are practiced to prevent water pollution:

(1) Construction of a clay or other type of liner beneath the planned waste disposal area to prevent infiltration of surface water (precipitation) or water contained in the waste into the ground-water system.

(2) Compaction of waste material to reduce infiltration.

(3) Maintenance of uniformly sized refuse to enhance good compaction (which may require additional crushing).

(4) Construction of a clay liner over the material to minimize infiltration. This is usually succeeded by placement of topsoil and seeding to establish a vegetative cover for erosion protection and runoff control.

(5) Excavation of diversion ditches surrounding the refuse disposal site to exclude surface runoff from the area. These ditches can also be used to collect seepage from refuse piles, with subsequent treatment, if necessary.

Surface runoff in the immediate area of beneficiation facilities presents another potential pollution problem. Runoff from haul roads, areas near conveyors, and ore storage piles is a potential source of pollutant loading to nearby surface waters. Several current industry practices to control this pollution are:

(1) Construction of ditches surrounding storage areas to divert surface runoff and collect seepage that does occur.

(2) Establishment of a vegetative cover of grasses in areas of potential sheet wash and erosion to stabilize the material, to control erosion and sedimentation, and to improve the aesthetic aspects of the area.

(3) Installation of hard surfaces on haul roads, beneath conveyors, etc., with proper slopes to direct drainage to a sump. Collected waters may be pumped to an existing treatment facility for treatment.

Another potential problem associated with construction of tailing-pond treatment systems is the use of existing valleys and natural drainage areas for impoundment of mine water or process facility process waste water. The capacity of these impoundment systems frequently is not large enough to prevent high discharge flow rates--particularly, during the late winter and early spring months. The use of ditches, flumes, pipes, trench drains, and dikes will assist in preventing runoff caused by snowmelt, rainfall, or streams from entering impoundments. Very often, this runoff flow is the only factor preventing attainment of zero discharge. Diversion of natural runoff from impoundment treatment systems, or construction of these facilities in locations which do not obstruct natural drainage, is therefore, desirable.

Ditches may be constructed upslope from the impoundment to prevent water from entering it. These ditches also convey water away and reduce the total volume of water which must be treated. This may result in decreased treatment costs, which could offset the costs of diversion.

Segregation or Combination of Mine and Process Facility Waste Waters

A widely adopted control practice in the ore mining and dressing industry is the use of mine water as a source of process water. In many areas, this is a highly desirable practice, because it serves as a water-conservation measure. Waste constituents may thus be concentrated into one waste stream for treatment. In other cases, however, this practice results in the necessity for discharge from a process facility-water impoundment system because, even with recycle of part of the process water, a net positive water balance results.

At several sites visited as part of this study, degradation of the mine water quality is caused by combining the wastewater streams for treatment at one location. A negative effect results because water with low pollutant loading serves to dilute water of higher pollutant loading. This often results in decreased water-treatment efficiency because concentrated waste streams can often be treated more effectively than dilute waste streams. The mine water in these cases may be treated by relatively simple methods; while the volume of waste water treated in the process facility impoundment system will be reduced, this water will be treated with increased efficiency.

There are also locations where the use of mine water as process water has resulted in an improvement in the ultimate effluent. Choice of the options to segregate or combine waste water treatment for mines and process facilities must be made on an individual basis, taking into account the character of the waste water to be treated (at both the mine and the process facility), the water balance in the mine/process facility system, local climate, and topography. The ability of a particular operation to meet zero or reduced effluent levels may be dependent upon this decision at each location.

Regrading

Surface mining may often require removal of large amounts of overburden to expose the ores to be exploited. Regrading involves mass movement of material following ore extraction to achieve a more desirable land configuration. Reasons for regrading strip mined land are:

(1) aesthetic improvement of land surface
(2) returning usefulness to land
(3) providing a suitable base for revegetation
(4) burying pollution-forming materials, e.g. heavy metals
(5) reducing erosion and subsequent sedimentation
(6) eliminating landsliding
(7) encouraging natural drainage
(8) eliminating ponding
(9) eliminating hazards such as high cliffs and deep pits
(10) controlling water pollution

Contour regrading is currently the required reclamation technique for many of the nations's active contour and area surface mines. This technique involves regrading a mine to approximate original land contour. It is generally one of the most favored and aesthetically pleasing regrading techniques because the land is returned to its approximate premined state. This technique is also favored because nearly all spoil is placed back in the pit, eliminating oversteepened downslope spoil banks and reducing the size of erodable reclaimed area. Contour regrading facilitates deep burial of pollution-forming materials and minimizes contact time between regraded spoil and surface runoff, thereby reducing erosion and pollution formation.

However, there are also several disadvantages to contour regrading that must be considered. In area and contour stripping, there may be other forms of reclamation that provide land configurations and slopes better suited to the intended uses of the land. This can be particularly true with steepslope contour strips, where large, high walls and steep final spoil slopes limit application of contour regrading. Mining is, therefore, frequently prohibited in such areas, although there may be other regrading techniques that could be effectively utilized. In addition, where extremely thick ore bodies are mined beneath shallow overburden, there may not be sufficient spoil material remaining to return the land to the original contour.

There are several other reclamation techniques of varying effectiveness which have been utilized in both active and abandoned mines. These techniques include terrace, swale, swallow-tail, and Georgia V-ditch, several of which are quite similar in nature. In employing these techniques, the upper high-wall portion is frequently left exposed or backfilled at a steep angle, with the spoil outslope remaining somewhat steeper than the original contour. In all cases, a terrace of some form remains where the original bench was located, and there are provisions for rapidly channeling runoff from the spoil area. Such terraces may permit more effective utilization of surface-mined land in many cases.

Disposal of excess spoil material is frequently a problem where contour backfilling is not practiced. However, the same problem can also occur, although less commonly, where contour regrading is in use. Some types of overburden rock-particularly, tightly packed sandstones--substantially expand in volume when they are blasted and moved. As a result, there may be a large volume of spoil material that cannot be returned to the pit area, even when contour backfilling is employed. To solve this problem, head-of-hollow fill has been used for overburden storage. The extra overburden is placed in narrow, steep-sided hollows in compacted layers 1.2 to 2.4 meters (4 to 8 feet) thick and graded to control surface drainage.

In this regrading and spoil storage technique, natural ground is cleared of woody vegetation, and rock drains are constructed where natural drains exist, except in areas where inundation has occurred. This permits ground water and natural percolation to leave fill areas without saturating the fill, thereby reducing potential landslide and erosion problems. Normally, the face of the fill is terrace graded to minimize erosion of the steep outslope area.

This technique of fill or spoil material deposition has been limited to relatively narrow, steep-sided ravines that can be adequately filled and graded. Design considerations include the total number of acres in the watershed above a proposed head-of-hollow fill, as well as the drainage, slope stability, and prospective land use. Revegetation usually proceeds as soon as erosion and siltation protection have been completed. This technique is avoided in areas where under-drainage materials contain high concentrations of pollutants, since the resultant drainage would require treatment to meet pollution-control requirements.

Erosion Control

Although regrading is the most essential part of surface-mine reclamation, it cannot be considered a total reclamation technique. There are many other facets of surface-mine reclamation that are equally important in achieving successful reclamation. The effectivenesses of regrading and other control techniques are interdependent. Failure of any phase could severly reduce the effectiveness of an entire reclamation project.

The most important auxiliary reclamation procedures employed at regraded surface mines or refuse areas are water diversion and erosion and runoff control. Water diversion involves collection of water before it enters a mine area and conveyance of that water around the mine site, as discussed previously. This procedure decreases erosion and pollution formation. Ditches are usually excavated upslope from a mine site to collect and convey water. Flumes and pipes are used to carry water down steep slopes or across regraded areas. Riprap and dumped rock are sometimes used to reduce water velocity in the conveyance system.

Diversion and conveyance systems are designed to accommodate predicted water volumes and velocities. If the capacity of a ditch is exceeded, water erodes the sides and renders the ditch ineffective.

Water diversion is also employed as an actual part of the mining procedure. Drainways at the bases of high walls intercept and divert discharging ground water prior to its contact with pollution-forming materials. In some instances, ground water above the mine site is pumped out before it enters the mine area, where it would become polluted and require treatment. Soil erosion is significantly reduced on regraded areas by controlling the course of surface-water runoff, using interception channels constructed on the regraded surface.

Water that reaches a mine site, such as direct rainfall, can cause serious erosion, sedimentation, and pollution problems. Runoff-control techniques are available to effectively deal with this water, but these techniques may conflict with pollution-control measures. Control of chemical pollutants forming at a mine frequently involves reduction of water infiltration, while runoff controls to prevent erosion usually increase infiltration, which can subsequently increase pollutant formation.

There are a large number of techniques in use for controlling runoff, with highly variable costs and degrees of effectiveness. Mulching is sometimes used as a temporary measure which protects the runoff surface from raindrop impacts and reduces the velocity of surface runoff.

Velocity reduction is a critical facet of runoff control. This is accomplished through slope reduction by terracing or grading; revegetation; or use of flow impediments such as dikes, contour plowing, and dumped rock. Surface stabilizers have been utilized on the surface to temporarily reduce erodability of the material itself, but expense has restricted use of such materials in the past.

Revegetation

Establishment of good vegetative cover on a mine area is probably the most effective method of controlling runoff and erosion. A critical factor in mine revegetation is the quality of the soil or spoil material on the surface of a regraded mine. There are several methods by which the nature of this material has been controlled. Topsoil segregation during stripping is mandatory in many states. This permits topsoil to be replaced on a regraded surface prior to revegetation. However, in many forested, steep-sloped areas, there is little or no topsoil on the undisturbed land surface. In such areas, overburden material is segregated in a manner that will allow the most toxic materials to be placed at the base of the regraded mine, and the best spoil material is placed on the mine surface.

Vegetative cover provides effective erosion control; contributes significantly to chemical pollution control; results in aesthetic improvement; and can return land to agricultural, recreational, or silvicultural usefulness. A dense ground cover stabilizes the surface (with its root system), reduces velocity of surface runoff, helps build humus on the surface, and can virtually eliminate erosion. A soil profile begins to form, followed by a complete soil ecosystem. This soil profile acts as an oxygen barrier, reducing the amount of oxygen reaching underlying materials. This, in turn, reduces oxidation, which is a major contributing factor to pollutant formation.

The soil profile also tends to act as a sponge that retains water near the surface, as opposed to the original loose spoil (which allowed rapid infiltration). This water evaporates from the mine surface, cooling it and enhancing vegetative growth. Evaporated water also bypasses toxic materials underlying the soil, decreasing pollution production. The vegetation itself also utilizes large quantities of water in its life processes and transpires it back to the atmosphere, again reducing the amount of water reaching underlying materials.

Establishment of an adequate vegetative cover at a mine site is dependent on a number of related factors. The regraded surface of many spoils cannot support a good vegetative cover without supplemental treatment. The surface texture is often too irregular, requiring the use of raking to remove as much rock as possible and to decrease the average grain size of the remaining material. Materials toxic to plant life, usually buried during regrading, generally do not appear on or near the final graded surface. If the surface is compacted, it is usually loosened by discing, plowing, or roto-tilling prior to seeding in order to enhance plant growth.

Soil supplements are often required to establish a good vegetative cover on surface-mined lands and refuse piles, which are generally deficient in nutrients. Mine spoils are often acidic, and lime must be added to adjust the pH to the tolerance range of the species to be planted. It may be necessary to apply additional neutralizing material to revegetated areas for some time to offset continued pollutant generation.

Several potentially effective soil supplements are currently undergoing research and experimentation. Flyash is a waste product of coal-fired boilers and resembles soil with respect to certain physical and chemical properties. Flyash is often alkaline, contains some plant nutrients, and possesses moisture retaining and soil-conditioning capabilities. Its main function is that of an alkalinity source and a soil conditioner, although it must usually be augmented with lime and fertilizers. However, flyash can vary drastically in quality--particularly, with respect to pH--and may contain leachable materials capable of producing water pollution. Future research, demonstration, and monitoring of flyash supplements will probably develop the potential use of such materials.

Limestone screenings are also an effective long-term neutralizing agent for acidic spoils. Such spoils generally continue to produce acidity as oxidation continues. Use of lime for direct planting upon these surfaces is effective, but it provides only short-term alkalinity. The lime is usually consumed after several years, and the spoil may return to its acidic condition. Limestone screenings are of larger particle size and should continue to produce alkalinity on a decreasing scale for many years, after which a vegetative cover should be well-established. Use of large quantities of limestone should also add alkalinity to receiving streams. These screenings are often cheaper than lime, providing larger quantities of alkalinity for the same cost. Such applications of limestone are currently being demonstrated in several areas.

Use of digested sewage sludge as a soil supplement also has good possibilities for replacing fertilizer and simultaneously alleviating the problem of sludge disposal. Sewage sludge is currently being utilized for revegetation in strip-mined areas of Ohio. Besides supplying various nutrients, sewage sludge can reduce acidity or alkalinity and effectively increase soil absorption and moisture-retention capabilities. Digested sewage sludge can be applied in liquid or dry form and must be incorporated into the spoil surface. Liquid sludge applications require large holding ponds or tank trucks, from which sludge is pumped and sprayed over the ground, allowed to dry, and disced into the underlying material. Dry sludge application requires dryspreading machinery and must be followed by discing.

Limestone, digested sewage sludge, and flyash are all limited by their availabilities and chemical compositions. Unlike commercial fertilizers, the chemical compositions of these materials may vary greatly, depending on how and where they are produced. Therefore, a nearby supply of these supplements may be useless if it does not contain the nutrients or pH adjusters that are deficient in the area of intended application. Flyash, digested sewage sludge, and limestone screenings are all waste products of other processes and are, therefore, usually inexpensive. The major expense related to utilization of any of these wastes is the cost of transporting and applying the material to the mine area. Application may be quite costly and must be uniform to effect complete and even revegetation.

When such large amounts of certain chemical nutrients are utilized, it may also be necessary to institute controls to prevent chemical pollution of adjacent waterways. Nutrient controls may consist of preselection of vegetation to absorb certain chemicals, or of construction of berms and retention basins in which runoff can be collected and sampled, after which it can be discharged or pumped back to the spoil. The specific soil supplements and application rates employed are selected to provide the best possible conditions for the vegetative species that are to be planted.

Careful consideration should be given to species selection in surface-mine reclamation. Species are selected according to some land-use plan, based upon the degree of pollution control to be achieved and the site environment. A dense ground cover of grasses and legumes is generally planted, in addition to tree seedlings, to rapidly check erosion and siltation. Trees are frequently planted in areas of poor slope stability to help control landsliding. Intended future use of the land is an important consideration with respect to species selection. Reclaimed surface-mined lands are occasionally returned to high-use categories, such as agriculture, if the land has potential for growing crops. However, when toxic spoils are encountered, agricultural potential is greatly reduced, and only a few species will grow.

Environmental conditions--particularly, climate--are important in species selection. Usually, species are planted that are native to an area--particularly, species that have been successfully established on nearby mine areas with similar climate and spoil conditions.

Revegetation of arid and semi-arid areas involves special consideration because of the extreme difficulty of establishing vegetation. Lack of rainfall and effects of surface disturbance create hostile growth conditions. Because mining in arid regions has only recently been initiated on a large scale, there is no standard revegetation technology. Experimentation and demonstration projects exploring two general revegetation techniques--moisture retention and irrigation--are currently being conducted to solve this problem.

Moisture retention utilizes entrapment, concentration, and preservation of water within a soil structure to support vegetation. This may be obtained utilizing snow fences, mulches, pits, and other methods.

Irrigation can be achieved by pumping or by gravity, through either pipes or ditches. This technique can be extremely expensive, and acquisition of water rights may present a major problem. Use of these arid-climate revegetation techniques in conjunction with careful overburden segregation and regrading should permit return of arid mined areas to their natural states.

Exploration, Development, and Pilot-Scale Operations

Exploration activities commonly employ drilling, blasting, excavation, tunneling, and other techniques to discover, locate, or define the extent of an ore body. These activities vary from small-scale (such as a single drill hole) to large scale (such as excavation of an open pit or outcrop face). Such activities frequently contribute to the pollutant loading in waste water emanating from the site. Since available facilities (such as power sources) and ready accessibility of special equipment and supplies often are limited, sophisticated treatment is often not possible. In cases where exploration activity is being carried out, the scale of such operations is such that primary water-quality problems involve the presence of increased suspended-solid loads and potentially severe pH changes. Ponds should be provided for settling and retention of waste water, drilling fluids, or runoff from the site. Simple, accurate field tests for pH can be made, with subsequent pH adjustment by addition of lime (or other neutralizing agents).

Protection of receiving waters will thus be accomplished, with the possible additional benefits of removal of metals from solution--either in connection with solids removal or by precipitation from solution.

Development operations frequently are large-scale, compared to exploration activities, because they are intended to extend already known or currently exploited resources. Because these operations are associated with facilities and equipment already in existence, it is necessary to plan development activities to minimize pollution potential, and to use existing mine or process facility treatment and control methods and facilities. These operations should, therefore, be subject to limitations equivalent to existing operations with respect to effluent treatment and control.

Pilot-scale operations often involve small to relatively large mining and beneficiation facilities even though they may not be currently operating at full capacity or are in the process of development to full-scale. Planning of such operations should be undertaken with treatment and control of waste water in mind to ensure that effluent limitation guidelines and standards of performance for the category or subcategory will be met. Although total loadings from such operations and facilites are not at the levels expected from normal operating conditions, the compositions of wastes and the concentrations of waste water parameters are likely to be similar. Therefore, implementation of recommended treatment and control technologies must be accomplished.

Mine and Process Facility Closure

Mine Closure (Underground). Unless well-planned and well designed abatement techniques are implemented, an underground mine can be a permanent source of water pollution.

Responsibility for the prevention of any adverse environmental impacts from the temporary or permanent closure of a deep mine should rest solely and permanently with the mine operator. This constitutes a substantial burden; therefore, it behooves the operator to make use of the best technology available for dealing with pollution problems associated with mine closure. The two techniques most frequently utilized in deep-mine pollution abatement are treatment and mine sealing. Treatment technology is well defined and is generally capable of producing acceptable mine effluent quality. If the mine operator chooses this course, he is faced with the prospect of costly permanent treatment of each mine discharge.

Mine sealing is an attractive alternative to the prospects of perpetual treatment. Mine sealing requires the mine operator to consider barrier and ceiling-support design from the perspectives of strength, mine safety, their ability to withstand high water pressure, and their utility for retarding groundwater seepage. In the case of new mines, these considerations should be included in the mine design to cover the eventual mine closure. In the case of existing mines, these considerations should be evaluated for existing mine barriers and ceiling supports, and the future mine plan should be adjusted to include these considerations if mine sealing is to be employed at mine closure.

Sealing eliminates the mine discharge and inundates the mine workings, thereby reducing or terminating the production of pollutants. However, the possibility of the failure of mine seals or outcrop barriers increases with time as the sealed mine workings gradually became inundated by ground water and the hydraulic head increases. Depending upon the rate of ground-water influx and the size of the mined area, complete inundation of a sealed mine may require several decades. Consequently, the maximum anticipated hydraulic head on the mine seals may not be realized for that length of time. In addition, seepage through, or failure of, the barrier or mine seal could occur at any time. Therefore, the mine operator should be required to permanently maintain the seals, or to provide treatment in the event of seepage or failure.

Mine Closure (Surface). The objectives of proper reclamation management of closed surface mines and associated workings are to (1) restore the affected lands to a condition at least fully capable of supporting the uses which they were capable of supporting prior to any mining, and (2) achieve a stability which does not pose any threat to public health, safety, or water pollution. With proper planning and management during mining activities, it is often possible to minimize the amount of land disturbed or excavated at any one time. In preparation for the day the operation may cease, a reclamation schedule for restoration of existing affected areas, as well as those which will be affected, should be specified. The use of a planned methodology such as this will return the workings to their premined condition at a faster rate, as well as possibly reduce the ultimate costs to the operator.

To accomplish the objectives of the desired reclamation goals, it is mandatory that the surface-mine operator regrade and revegetate the disturbed area during, or upon completion of, mining. The final regraded surface configuration is dependent upon the ultimate land use of the specific site, and control practices described in this report can be incorporated into the regrading plan to minimize erosion and sedimentation. The operator should establish a diverse and permanent vegetative cover and a plant succession at least equal in extent of cover to the natural vegetation of the area. To assure compliance with these requirements and permanence of vegetative cover, the operator should be held responsible for successful revegetation and effluent water quality for a period of five full years after the last year of augmented seeding. In areas of the country where the annual average precipitation is 64 cm (26 in.) or less, the operator's assumption of responsibility and liability should extend for a period of ten full years after the last year of augmented seeding, fertilization, irrigation, or effluent treatment.

Process Facility Closure. As with closed mines, a beneficiation facility's potential contributions to water pollution do not cease upon shutdown of the facility. Tailing ponds, waste or refuse piles, haulage areas, workings, dumps, storage areas, and processing and shipping areas often present serious problems with respect to contributions to water pollution. Among the most important are tailing ponds, waste piles, and dump areas. Failure of tailing ponds can have catastrophic consequences, with respect to both immediate safety and water quality.

To protect against catastrophic occurrences, tailing ponds should be designed to accommodate, without overflow, an abnormal storm which is observed every 25 years. Since no waste water is contributed from the processing of ores (the facility being closed), the ponds will gradually become dewatered by evaporation or by percolation into the subsurface. The structural integrity of the tailing-pond walls should be periodically examined and, if necessary, repairs made. Seeding and vegetation can assist in stabilizing the walls, prevent erosion and sedimentation, lessen the probability of structural failure, and improve the aesthetics of the area.

Refuse, waste, and tailing piles should be recontoured and revegetated to return the topography as near as possible to the condition it was in before the activity. Techniques employed in surface-mine regrading and revegetation should be utilized. Where process facilitys are located adjacent to mine workings, the mines can be refilled with tailings. Care should be taken to minimize disruption of local drainage and to ensure that erosion and sedimentation will not result. Maintenance of such refuse or waste piles and tailing-disposal areas should be performed for at least five years after the last year of regrading and augmented seeding. In areas of the country where the annual average precipitation is 64 cm (26 in.) or less, the operator's assumption of responsibility should extend for a period of ten full years after the last year of augmented seeding, fertilization, irrigation, or effluent treatment.

Monitoring

Since most waste water discharges from these industries contain suspended solids as the principal pollutant, complex water analyses are not usually required. On the other hand, many of these industries today do little or no monitoring on waste water discharges. In order to obtain meaningful knowledge and control of their waste water quality, many mines and minerals processing facilities need to institute routine monitoring measurements of the few pertinent waste parameters.

SUSPENDED SOLIDS REMOVAL

The treatment technologies available for removing suspended solids from minerals mining and processing waste water are numerous and varied, but a relatively small number are widely used. The following shows the approximate breakdown of usage for the various techniques:

removal technique	percent of treatment facilities using technology
settling ponds (unlined)	95-97
settling ponds (lined)	<1
chemical flocculation (usually with ponds)	2-5
thickeners and clarifiers	2-5
hydrocyclones	<1
tube and lamella settlers	<1
screens	<1
filters	<1
centrifuges	<1

Settling Ponds

As shown above, the predominant treatment technique for removal of suspended solids involves one or more settling ponds. Settling ponds are versatile in that they perform several waste-oriented functions including:

(1) Solids removal. Solids settle to the bottom and the clear water overflow is much reduced in suspended solids content.

(2) Equalization and water storage capacity. The clear supernatant water layer serves as a reservoir for reuse or for controlled discharge.

(3) Solid waste storage. The settled solids are provided with long term storage.

This versatility, ease of construction and relatively low cost, explains the wide application of settling ponds as compared to other technologies.

The performance of these ponds depends primarily on the settling characteristics of the solids suspended, the flow rate through the pond and the pond size. Settling ponds can be used over a wide range of suspended solids levels. Often a series of ponds is used, with the first collecting the heavy load of easily settled material and the following ones providing final polishing to reach a desired level. suspended level. As the ponds fill with solids they can be dredged to remove these solids or they may be left filled and new ponds provided. The choice often depends on whether land for additional new ponds is available. When suspended solids levels are low and ponds large, settled solids build up so slowly that neither dredging nor pond abandonment is necessary, at least not for a period of many years.

Settling ponds used in the minerals industry range from small pits, natural depressions and swamp areas to engineered thousand acre structures with massive retaining dams and legislated construction design. The performance of these ponds can vary from excellent to poor, depending on character of the suspended particles, and pond size and configuration.

In general the current experience in this industry segment with settling ponds shows reduction to 50 mg/l or less, but for some waste waters the discharge may still contain up to 150 mg/l of TSS. Performance data of some settling ponds found in the dimension stone, crushed stone, construction sand and gravel, and industrial sand subcategories is given in Table 12.

Eighteen of these 20 facility samples show greater than 95 percent reduction of TSS by ponding. There appear to be no correlations within a sampled subcategory due to differences in quality of intake water, mined product, or processing.

Table 12
Settling Pond Performance
Stone, Sand and Gravel Operations

	TSS (mg/l		Percent	Treatment
Plant	Influent	Effluent	Reduction	Chemical
Dimension Stone				
3001	1,808	37	97.95	none
3003	3,406	34	99	$FeCl_3$,sodium bicarbonate
3007	2,178	80	96.3	none
Crushed Stone				
1001	1,054	8	99.24	none
1003	7,68	8	99.92	none
1004	5,710	12	99.79	none
1021	7,206	28	99.61	none
(2 ponds)	772	3	99.61	none
1039	10,013	14	99.86	none
1053	21,760	56	99.74	none
Construction Sand and Gravel				
1017 (D)	5,712	51	99.12	flocculating
1044	5,114	154	96.99	none
1083 (A)	20,660	47	99.77	none
1083 (B)	8,863	32	99.64	none
1129	4,660	44	99.06	none
1247 (D)	93	29	68.82	flocculating agent
1391	12,700	18	99.86	none
Industrial Sand				
1019	2,014	56	97.22	none
1101	427	56	86.88	none
1102	2,160	66	96.94	flocculating

D - Dredge
A - Main Plant
B - Auxiliary Plant

Laboratory settling data collected on samples of the pond influent waste water from six of the sand and gravel facilities contained in the above data show that under controlled conditions they can be settled within 24 hours to a range of 20-450 mg/l of suspended solids, and, with the addition of commercial coagulant can be settled to a range of 10-60 mg/l in the same time period. These laboratory data are consistent with the pond performance measured above.

In this segment of the mineral industry, settling is usually a prelude to recycle of water for washing purposes. At this point the level of suspended solids commonly viewed as acceptable in recycled water used for construction materials washing is 200 mg/l. Every facility in the above sample achieved this level with values ranging from 3 to 154 mg/l. Thus the TSS levels obtained after settling in ponds are apparently under present practices adequate for recycling purposes in this industry segment.

Much of the poor performance exhibited by the settling ponds employed by the minerals industry is due to the lack of understating of settling techniques. This is demonstrated by the construction of ponds without prior determination of settling rate and detention time. In some cases series of ponds have been claimed to demonstrate a company's mindfullness of environmental control when in fact all the component ponds are so poorly constructed and maintained that they could be replaced by one pond with less surface area than the total of the series.

The chief problems experienced by settling ponds are rapid fill-up, insufficient retention time and the closely related short ciruciting. The first can be avoided by constructing a series of ponds as mentioned above. Frequent dredging of the first if needed will reduce the need to dredge the remaining ponds. The solution to the second involves additional pond volume or use of flocculants. The third problem, however, is almost always overlooked. Short circuiting is simply the formation of currents or water channels from pond influent to effluent whereby whole areas of the pond are not utilized. The principles of clarifier construction apply here. The object is to achieve a uniform plug flow from pond influent to effluent. This can be achieved by proper inlet-outlet construction that forces water to be uniformly distributed at those points, such as a weir. Frequent dreding or insertion of baffles will also minimize channelling. The EPA report "Waste water Treatment Studies in Aggregate and Concrete Production" (reference 25) in detail lists the procedure one should follow in designing and building settling ponds.

Clarifiers and Thickeners

An alternative method of removing suspended solids is the use of clarifiers or thickeners which are essentially tanks with internal baffles, compartments, sweeps and other directing and segregating mechanisms to provide efficient concentration and removal of suspended solids in one effluent stream and clarified liquid in the other.

Clarifiers differ from thickeners primarily in their basic purpose. Clarifiers are used with the main purpose of producing a clear overflow with the solids content of the sludge underflow being of secondary importance. Thickeners, on the other hand, have the basic purpose of producing a high solids underflow with the character of the clarified overflow being of secondary importance. Thickeners are also usually smaller in size but more massively constructed for a given throughput.

Clarifiers and thickeners have a number of distinct advantages over ponds:

(1) Less land space is required. Since these devices are much more efficient in settling capacity than ponds.

(2) Influences of rainfall are much less than for ponds. If desired the clarifiers and thickeners can even be covered.

(3) Since the external construction of clarifiers and thickeners consist of concrete or steel tanks ground seepage and rain water runoff influences do not exist.

On the other hand, clarifiers and thickeners suffer some distinct disadvantages as compared with ponds:

(1) They have more mechanical parts and maintenance.

(2) They have only limited storage capacity for either clarified water or settled solids.

(3) The internal sweeps and agitators in thickeners and clarifiers require more power and energy for operation than ponds.

Clarifiers and thickeners are usually used when sufficient land for ponds is not available or is very expensive.

Hydrocyclones

While hydrocyclones are widely used in the separation, classification and recovery operations involved in minerals processing, they are used only infrequently for waste water treatment. Even the smallest diameter units available (stream velocity and centrifugal separation forces both increase as the diameter decreases) are ineffective when particle size is less than 25-50 microns. Larger particle sizes are relatively easy to settle by means of small ponds, thickeners or clarifiers or other gravity principle settling devices. It is the smaller suspended particles that are the most difficult to remove and it is these that can not be removed by hydrocyclones but may be handled by ponds or other settling technology. Also hydrocyclones are of doubtful effectiveness when flocculating agents are used to increase settling rates.

Hydrocyclones are used as scalping units to recover small sand or other mineral particles in the 25 to 200 micron range, particularly if the recovered material can be sold as product. In this regard hydrocyclones may be considered as converting part of the waste load to useful product as well as providing the first step of waste water treatment. Where land availability is a problem, a bank of hydrocyclones may serve in place of a primary settling pond.

Tube and Lamella Settlers

Tube and lamella settlers require less land area than clarifiers and thickeners. These compact units, which increase gravity settling efficiency by means of closely packed inclined tubes and plates, can be used for either scalping or waste water polishing operations depending on throughput and design.

Centrifuges

Centrifuges are not widely used for minerals mining waste water treatment. Present industrial-type centrifuges are relatively expensive and not particularly suited for this purpose. Future use of centrifuges will depend on regulations, land space availability and the development of specialized units suitable for minerals mining operations.

Flocculation

Flocculating agents increase the efficiency of settling facilities and they are of two general types: ionic and polymeric. The ionic types such as alum, ferrous sulfate and ferric chloride function by neutralizing the repelling double layer ionic charges around the suspended particles, thereby allowing the particles to attract each other and agglomerate. Polymeric types function by physically agglomerating the particles.

Flocculating agents are most commonly used after the larger, more readily settled particles (and loads) have been removed by a settling pond, hydrocyclone or other such scalping treatment. Agglomeration, or flocculation, can then be achieved with less reagent and less settling load on the polishing pond or clarifier.

Flocculation agents can be used with minor modifications and additions to existing treatment systems, but the costs for the flocculating chemicals are often significant. Ionic types are used in 10 to 100 mg/l concentrations in the waste water while the higher priced polymeric types are effective in the 2 to 20 mg/l concentrations.

Flocculants have been used by several segments within the minerals industry with varying degrees of success. The use of flocculants particularly for the hard to settle solids is more of an art than a science, since it is frequently necessary to try several flocculants at varying concentrations.

Screens

Screens are widely used in minerals mining and processing operations for separations, classifications and beneficiations. They are similar to hydrocyclones in that they are restricted to removing the larger (<50-100 micron) particle size suspended solids of the waste water, which can then often be sold as useful product. Screens are not practical for removing the smaller suspended particles.

Filtration

Filtration is accomplished by passing the waste water stream through solids-retaining screens, cloths, or particulates such as sand, gravel, coal or diatomaceous earth using gravity, pressure or vacuum as the driving force. Filtration is versatile in that it can be used to remove a wide range of suspended particle sizes.

The large volumes of many waste water streams found in minerals mining operations require large filters. The cost of these units and their relative complexity, compared to settling ponds, has restricted their use to a few industry segments committed to complex waste water treatment.

DISSOLVED MATERIAL TREATMENTS

Unlike ubiquitous suspended solids which need to be removed from minerals mining and processing waste waters, dissolved materials are a problem only in scattered instances in the industries covered herein.

Treatments for dissolved materials are based on either modifying or removing the undesired materials. Modification techniques include chemical treatments such as neutralization. Acids and alkaline materials are examples of dissolved materials modified in this way. Most removal of dissolved solids is accomplished by chemical precipitation. An example of this is given below, the removal of fluoride by liming:

$$2F^- + Ca(OH)_2 = CaF_2 + 2OH^-$$

With the exception of pH adjustment, chemical treatments for abatement of waterborne wastes are not common in this industry segment.

Neutralization

Some of the waterborne wastes of this study, often including mine drainage water, are either acidic or alkaline. Before disposal to surface water or other medium, excess acidity or alkalinity needs to be controlled to the range of pH 6 to 9. The most common method is to treat acidic streams with alkaline materials such as limestone, lime, soda ash, or sodium hydroxide. Alkaline streams are treated with acids such as sulfuric. Whenever possible, advantage is taken of the availability of acidic waste streams to neutralize basic waste streams and vice versa. Neutralization often produces suspended solids which must be removed prior to waste water disposal.

pH Control

The control of pH may be equivalent to neutralization if the control point is at or close to pH 7. Sometimes chemical addition to waste streams is designed to maintain a pH level on either the acidic or basic side for purposes of controlling solubility.

An example of pH control being used for precipitating undesired pollutants is:

$$(1) \quad Fe^{+3} + 3OH^- = Fe(OH)_3$$

This reaction is used for removal of iron contaminants.

SUMMARY OF TREATMENT TECHNOLOGY APPLICATIONS, LIMITATIONS AND RELIABILITY

Table 13 summarizes comments on the various treatment technologies as they are utilized for the minerals mining industry. Estimates of the efficiency with which the treatments remove suspended or dissolved solids from waste water as given in the table need to be interpreted in the following context.

These values will obviously not be valid for all circumstances, concentrations or materials, but should provide general guidance for treatment performance capabilities. Several comments may be made concerning the values:

(1) At high concentrations and optimum conditions, all treatments can achieve 99 percent or better removal of the desired material;

(2) At low concentrations, the removal efficiency drops off.

(3) Minimum concentration ranges achievable will not hold in every case. For example, pond settling of some suspended solids might not achieve less than the 100 mg/l level. This is not typical, however, since many such pond settling treatments can achieve 10 to 20 mg/l without difficulty. Failure to achieve the minimum concentration levels listed usually means that either the wrong treatment methods have been selected or that an additional treatment step is necessary (such as a second pond or a polish filtration).

PRETREATMENT TECHNOLOGY

Most construction minerals mining operations have waste water containing only suspended solids. Suspended solids is a compatible pollution parameter for publicly-owned activated sludge or trickling filter wastewater treatment facilities. However, most of these mining and processing operations are located in isolated regions and have no access to these treatment facilities. No instances of discharge to publicly-owned treatment facilities were found in the industry segment of this volume.

In the relatively few instances where dissolved materials are a problem, pH control and some reduction of hazardous constituents such as fluoride would be required. Lime treatment is usually sufficient to accomplish this.

TABLE 13. Summary of Technology, Applications, Limitations and Reliability

Waste Water Constituents	Treatment Process	Application	Percent Solids Removal	Expected Concentration (mg/l)	Minimum Concentration Achievable (mg/l)	Availability of Equipment	Lead Time (months)	Space or Land Needed	Maintenance Required	Sensitivity to Shock Loads	Effects of Shutdown and Startup	Energy Requirements
Suspended Solids	(1) Pond Settling	Used for all concentrations	60-99	5-200	5-30	none needed	1-12	large 1-500 acres small 0.05-1.0 acres	small	small	small	small
	(2) Clarifier Thickeners	Used for all concentrations	60-99	5-1000	5-30	readily available	3-24	<1 acre	nominal	sensitive	nominal	nominal
	(3) Hydrocyclones	Removal of larger particle sizes	50-99	--	--	ready available	3-12	approx. 10' x 10'	small	sensitive	small	small
	(4) Tube and Lamella Settlers	Removal of smaller particle sizes	90-99	--	--	readily available	3-12	approx. 10' x 10'	small	sensitive	nominal	small
	(5) Screens	Removal of larger particle sizes	50-99	--	--	ready available	3-12	approx. 10' x 10'	nominal	small	small	small
	(6) Rotary Vacuum Filters	Mainly for sludges and other high suspended solids streams	90-99	5-1000	5-30	readily available	3-12	approx. 10' x 10'	nominal	sensitive	nominal	nominal
	(7) Solid Bowl Centrifuge	Mainly for sludges and other high suspended solids streams	60-99	--	--	readily available	3-12	approx. 10' x 10'	nominal	sensitive	small	nominal
	(8) Leaf and Pressure Filters	Used over wide concentration range	90-99	10-100	5-30	readily available	3-6	approx. 10' x 10'	small	sensitive	small	small
	(9) Cartridge and Candle Filters	Mainly for polishing filtrations of suspended solids	50-99	2-10	2-10	readily available	1-3	approx. 10' x 10'	small	sensitive	small	small
	(10) Sand and Mixed Media Filters	Mainly for polishing filtrations of suspended solids	50-99	2-50	2-10	readily available	3-6	approx. 10' x 10'	small	sensitive	small	small
Dissolved Solids	(1) Neutralization and pH Control	General	99	NA	NA	readily available	3-12	small 20' x 20' or less	minor	nominal	small	small
	(2) Precipitation	Broadly used to remove solubles	50-99	0-20	0-10	readily available	3-6	small 20' x 20'	minor	sensitive	small	small

NON-WATER QUALITY ENVIRONMENTAL ASPECTS, INCLUDING ENERGY REQUIREMENTS

The effects of these treatment and control technologies on air pollution, noise pollution, and radiation are usually small and not of any significance.

Large amounts of solid waste in the form of both solids and sludges are formed as a result of all suspended solids operations as well as chemical treatments for neutralization, and precipitations. Easy-to-handle, relatively dry solids are usually left in settling ponds or dredged out periodically and dumped onto the land. Since mineral mining properties are usually large, space for such dumping is often available.

For those waste materials considered to be non-hazardous where land disposal is the choice for disposal, practices similar to proper sanitary landfill technology may be followed. The principles set forth in the EPA's Land Disposal of Solid Wastes Guidelines (CFR Title 40, Chapter 1; Part 241) may be used as guidance for acceptable land disposal techniques.

For those waste materials considered to be hazardous, disposal will require special precautions. In order to ensure long-term protection of public health and the environment, special preparation and pretreatment may be required prior to disposal. If land disposal is to be practiced, these sites must not allow movement of pollutants such as fluoride and radium-226 to either ground or surface water. Sites should be selected that have natural soil and geological conditions to prevent such contamination or, if such conditions do not exist, artificial means (e.g., liners) must be provided to ensure long-term protection of the environment from hazardous materials. Where appropriate, the location of solid hazardous materials disposal sites should be permanently recorded in the appropriate office of the legal jurisdiction in which the site is located.

In summary, the solid wastes and sludges from the mineral mining industry waste water treatments are very large in quantity. Since these industries generally have sufficient space and earth-moving capabilities, they manage it with greater ease than most other industries.

For the best practicable control technology currently available the added annual energy requirements are estimated to be 1.45×10^{11} kcal. This amounts to estimated 13 percent increase in the present estimated energy use for pollution control technologies in this segment of the mineral mining and processing industry. Over 80 percent of this added energy requirement is attributed to wet processing of crushed stone.

SECTION VIII

COST, ENERGY, WASTE REDUCTION BENEFITS AND NON-WATER ASPECTS OF TREATMENT AND CONTROL TECHNOLOGIES

SUMMARY

The construction materials segment of the mineral mining and processing industry has very large volumes of both products and waste water for treatment. Overall industry waste water treatment costs reflect this. Unlike manufacturing operations, where raw materials for the process may be selected and controlled as to purity and uniformity, construction materials mining and processing operations are themselves largely controlled by the purity and uniformity of the ores or raw materials involved. Operations have to be located at or near the mineral deposits. Since they are mostly low cost commodities, used mainly in urban or suburban areas the mining and processing must normally be done close to market outlets. Both availability and cost for land necessary for treatment are significantly influenced by this necessary location. Suburban and urban land is becoming more difficult to obtain and more costly.

Treatment costs often vary widely with the character of pollutants involved. A salient example involves the wide variation of of suspended solids. Effluents with large particle size wastes have high settling rates while small or colloidal suspended particles are slow and difficult to settle, requiring large ponds or thickeners, flocculating treatments or other devices for removing suspended solids in many cases.

As land costs increase, more sophisticated treatment technologies will come into use that require less land space. These include the use of flocculants and coagulants to induce more rapid pond settling and mechanical settling and separation devices such as thickeners and clarifiers, tube and lamella separators, filters, centrifuges and hydrocyclones.

In general, facility size and age have little influence on the type of waste effluent. The amounts and costs for their treatment and disposal are readily scaled from facility size and are not greatly affected by facility age.

Geographical location is important. Mines and processing facilities located in dry western areas rarely require major waste water treatment or have subsequent disposal problems.

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Terrain and land availability are also significant factors affecting treatment technology and costs. Lack of sufficient flat space for settling ponds forces utilization of mechanical thickeners, clarifiers, or settlers. On the other hand, advantage is often taken of valleys, hills, swamps, gullies and other natural configurations to provide low cost pond and solid waste disposal facilities.

In view of the large number of mines and beneficiation facilities and the significant variables listed above, costs have been developed for representative mines and processing facilities rather than specific facilities that may have advantageous geographical, terrain or ore composition. A summary of cost and energy information for the present level of waste water treatment technology for this segment is given in Table 14. Present capital investment for waste water treatment in the construction materials segment is estimated as $141,000,000.

COST REFERENCES AND RATIONALE

Cost information contained in this report was assembled directly from industry, from waste treatment and disposal contractors, engineering firms, equipment suppliers, government sources, and published literature. Whenever possible, costs are taken from actual installations, engineering estimates for projected facilities as supplied by contributing companies, or from waste treatment and disposal contractors quoted prices. In the absence of such information, cost estimates have been developed insofar as possible from facility-supplied costs for similar waste treatments and disposal for other facilities or industries.

Interest Costs and Equity Financing Charges

Capital investment estimates for this study have been based on 10 percent cost of capital, representing a composite number for interest paid or return on investment required.

Time Basis for Costs

All cost estimates are based on August 1972 prices and when necessary have been adjusted to this basis using the chemical engineering facility cost index.

Useful Service Life

The useful service life of treatment and disposal equipment varies depending on the nature of the equipment and process involved, its usage pattern, maintenance care and numerous other factors. Individual companies may apply service lives based on their actual experience for internal amortization.

TABLE 14
CAPITAL INVESTMENTS AND ENERGY CONSUMPTION OF PRESENT WASTEWATER TREATMENT FACILITIES

Subcategory	Capital Spent (dollars)	Present Energy Use (kcal x 10^6)	Total Annual Costs ($/kkg produced)
Dimension Stone	1,100,000	4,000	0.20
Crushed Stone, Dry	. . . . no waste water		
Crushed Stone, Wet	26,400,000	659,500	0.07
Crushed Stone, Flotation	50,000	1,400	0.07
Crushed Shell, Dredging	. . . . no waste water treatment . .		
Construction S&G, Dry	. . . . no waste water		
Construction S&G, Wet	90,000,000	325,000	0.08
Construction S&G, (dredging with on-land processing)	3,130,000	11,100	0.08
Construction S&G, (dredging with on-board processing)	. . . . no waste water treatment . .		
Industrial Sand, Dry	220,000	small	0.02
Industrial Sand, Wet	8,860,000	37,800	0.18
Industrial Sand, (acid and alkaline flotation)	8,770,000	30,200	0.20
Industrial Sand, (HF flotation)	120,000	500	0.23
Gypsum, Dry	. . . . no waste water		
Gypsum, Wet Scrubber	small	small	0.01
Gypsum, Heavy media separation	30,000	small	0.05
Bituminous Limestone	. . . . no waste water		
Oil Impregnated Diatomite	. . . . no waste water		
Gilsonite	25,000	125	0.08
Asbestos, Dry	. . . . no waste water		
Asbestos, Wet	25,000	small	0.09
Wollastonite	. . . . no process water		
Perlite	. . . . no process water		
Pumice	< 50,000	small	0.01
Vermiculite	620,000	2,400	0.62
Mica, Dry Processing	. . . . no process waste water . .		
Mica, Wet Grinding	small	small	0.22
Mica, Wet Ben. w/o clay by-products	780,000	3,100	5.0
Mica, Wet Ben. with clay by-products	550,000	2,300	5.5
TOTAL	141,000,000	1,080,000	---

Internal Revenue Service provides guidelines for tax purposes which are intended to approximate average experience. Based on discussions with industry and condensed IRS guideline information, the following useful service life values have been used:

(1) General process equipment	10 years
(2) Ponds, lined and unlined	20 years
(3) Trucks, bulldozers, loaders and other such materials handling and transporting equipment.	5 years

Depreciation

The economic value of treatment and disposal equipment and facilities decreases over its service life. At the end of the useful life, it is usually assumed that the salvage or recovery value becomes zero. For IRS tax purposes or internal depreciation provisions, straight line, or accelerated write-off schedules may be used. Straight line depreciation was used solely in this report.

Capital Costs

Capital costs are defined as all front-end out-of-pocket expenditures for providing treatment/disposal facilities. These costs include costs for research and development necessary to establish the process, land costs when applicable, equipment, construction and installation, buildings, services, engineering, special start-up costs and contractor profits and contingencies.

Annual Capital Costs

Most if not all of the capital costs are accrued during the year or two prior to actual use of the facility. This present worth sum can be converted to equivalent uniform annual disbursements by utilizing the Capital Recovery Factor Method:

$$\text{Uniform Annual Disbursement} = \frac{P\ i\ (1+i)\text{nth power}}{(1+i)\text{nth power} - 1}$$

Where P = present value (capital expenditure), i = interest rate, %/100, n = useful life in years

The capital recovery factor equation above may be rewritten as:

$$\text{Uniform Annual Disbursement} = P(\text{CR} - i\% - n)$$

Where (CR - i% - n) is the Capital Recovery Factor for i% interest taken over "n" years useful life.

Land Costs

Land-destined solid wastes require removal of land from other economic use. The amount of land so tied up will depend on the treatment/disposal method employed and the amount of wastes involved. Although land is non-depreciable according to IRS regulations, there are numerous instances where the market value of the land for land-destined wastes has been significantly reduced permanently, or actually becomes unsuitable for future use due to the nature of the stored waste. The general criteria applied to costing land are as follows:

(1) If land requirements for on-site treatment/disposal are not significant, no cost allowance is applied.
(2) Where on-site land requirements are significant and the storage or disposal of wastes does not affect the ultimate market value of the land, cost estimates include only interest on invested money.
(3) For significant on-site land requirements where the ultimate market value and/or availability of the land has been seriously reduced, cost estimates include both capital depreciation and interest on invested money.
(4) Off-site treatment/disposal land requirements and costs are not considered directly. It is assumed that land costs are included in the overall contractor's fees along with its other expenses and profit.
(5) In view of the extreme variability of land costs, adjustments have been made for individual industry situations. In general, isolated, plentiful land has been costed at $2,470/hectare ($1,000/acre).

Operating Expenses

Annual costs of operating the treatment/disposal facilities include labor, supervision, materials, maintenance, taxes, insurance and power and energy. Operating costs combined with annualized capital costs equal the total costs for treatment and disposal. No interest cost was included for operating (working) capital. Since working capital might be assumed to be one sixth to one third of annual operating costs (excluding depreciation), about 1-2 percent of total operating costs might be involved. This is considered to be well within the accuracy of the estimates.

Rationale for Representative Facilities

All facility costs are estimated for representative facilities rather than for any actual facility. Representative facilities are defined to have a size and age agreed upon by a substantial fraction of the manufacturers in the subcategory producing the given mineral, or, in the absence of such a consensus, the arithmetic average of production size and age for all facilities. Location is selected to represent the industry as closely as possibly. For instance, if all facilities are in northeastern U.S., typical location is noted as "northeastern states". If locations are widely scattered around the U.S., typical location would be not specified geographically. It should be noted that the unit costs to treat and dispose of hazardous wastes at any given facility may be considerably higher or lower than the representative facility because of individual circumstances.

Definition of Levels of Treatment and Control

Costs are developed for various types and levels of technology:

Minimum (or basic level). That level of technology which is equalled or exceeded by most or all of the involved facilities. Usually money for this treatment level has already been spent (in the case of capital investment) or is being spent (in the case of operating and overall costs).

B,C,D,E---Levels - Successively greater degrees of treatment with respect to critical pollutant parameters. Two or more alternative treatments are developed when applicable.

Rationale for Pollutant Considerations

(1) All non-contact cooling water is exempted from treatment (and treatment costs) provided that it is not contaminated by process water and no harmful pollutants are introduced.
(2) Water treatment, cooling tower and boiler blowdown discharges are not treated provided they are not contaminated by process water and contain no harmful pollutants.
(3) Removal of dissolved solids, other than harmful pollutants, is not included.
(4) Mine drainage treatments and costs are generally considered separately from process water treatment and costs. Mine drainage costs are estimated for all mineral categories for which such costs are a significant factor.

(5) All solid waste disposal costs are included as part of the cost development.

Cost Variances

The effects of age, location, and size on costs for treatment and control have been considered and are detailed in subsequent sections for each specific subcategory.

INDUSTRY STATISTICS

The estimated 1972 selling prices for the individual minerals in this report are summarized as follows. These values were taken from minerals industry yearbooks and Bureau of Census Publications.

Mineral Product	Estimated 1972 Selling Price Range, $/kkg ($/ton)	
crushed stone	1.90	(1.72)
construction sand and gravel	1.36	(1.23)
industrial sand	4.20	(3.81)
gypsum	4.10	(3.75)
asbestos	112	(102)
dimension stone	19.80	(18.00)
wollastonite	44	(40)
bituminous limestone	2.20 est.	(2.00)
gilsonite	unknown	
oil impregnated diatomite	71.71	(65.19)
perlite	12.47	(11.34)
pumice	1.88	(1.71)
vermiculite	26.41	(24.01)
mica	29.93	(27.21) minimum

INDIVIDUAL MINERAL WASTE WATER TREATMENT AND DISPOSAL COSTS

DIMENSION STONE

Of the sixteen facilities visited, thirteen use settling ponds for removal of suspended solids from waste water, two had no treatment and the other facility uses a raked settling tank. Approximately one-third of these facilities have total recycle after settling. Pond settling and recycle costs are given in Table 15. Since pond cost is the major investment involved, cost for settling without recycling is similar.

Cost Variances

Age. The sixteen visited facilities range from 10 to 142 years. There was no discernible correlation between facility age and treatment technology or costs.

Location. The facilities in this category are widely scattered around the U.S. The general low level of waste water treatment costs for dimension stone facilities exists independently of location.

Size. Facility sizes ranged from 2,720 to 64,100 kkg/yr (3,000 to 70,650 tons/yr). Since pond costs vary significantly with size in the less than one acre category, cost variance with size may be estimated to be 0.8 exponential for capital and linear for operating expenses.

Cost Basis for Table 15

Waste water treatment cost details for the typical facility values at Level C are shown below. Level B costs are similar except for recycle equipment.

Production: 18,000 kkg/yr (20,000 tons/yr)
8 hr/day; 250 days/yr

Water Use and Waste Characteristics:

4,170 l/kkg (1,000 gal/ton) of product
2% of product in effluent stream
5,000 mg/l TSS in raw effluent
360 kkg/yr (400 tons/yr) waste, dry basis
280 cu. m. (10,000 cu. ft.) wet sludge per year
1,300 kg solids per cu. m. sludge (80 lb/cu. ft.)

Treatment: Recycle of wash water after passing through a one acre settling pond

TABLE 15

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Dimension Stone

PLANT SIZE 18,000 METRIC TONS PER YEAR OF Product

PLANT AGE 50 YEARS PLANT LOCATION near population center

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		0	10,000	13,600		
ANNUAL CAPITAL RECOVERY		0	1,600	2,200		
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		0	900	950		
ANNUAL ENERGY AND POWER		0	200	400		
TOTAL ANNUAL COSTS		0	2,800	3,550		
COST/METRIC TON product		0	0.16	0.20		
WASTE LOAD PARAMETERS (kg/metric ton of product)	RAW WASTE LOAD					
Suspended Solids	20	20	0.8	0		

LEVEL DESCRIPTION:

A — direct discharge
B — settling, discharge
C — settling plus recycle

Cost Rational:

Pond cost	$10,000/acre
Total pipe cost	$1/diam/linear ft.
Total pump cost	$100/HP
Power costs	$0.02/kwh
Maintenance	5% of capital
Taxes and insurance	2% of capital
Capital recovery factor	0.1627

CRUSHED STONE

The crushed stone industry produces approximately one billion tons annually. Of this, approximately 75 percent is limestone and 25 percent is granite. The industry has been subcategorized in the following manner:

(1) dry process
(2) wet process
(3) flotation

DRY PROCESS

An estimated seventy percent of the crushed granite and limestone facilities use no contact process water. There are estimated 3,200 facilities in this category, accounting for 640 million kkg/yr (700 million tons/yr).

WET PROCESS

Typical Facility Data

A typical wet crushed stone operation is assumed to produce 180,000 kkg/yr (200,000 tons/yr), half of which is washed, and half is dry processed. The assumed wash water usage is 1,000 l/kkg (240 gal/ton), and the assumed waste content is 6% of the raw material. The cost data are presented in Table 16.

Waste water Treatment

Levels B and C - Simple Settling, Discharge, or Recycle

The waste water is passed through a one acre settling pond and discharged or recycled back to the facility. The pond is dredged periodically and the sludge is deposited on site.

Level D - Settling With Flocculants, Recycle

The waste water is treated with a flocculant and passed through a one acre settling pond. The effluent is then recycled. It is rare that a flocculant would be needed to produce an effluent quality acceptable for recycle in a crushed stone operation.

Cost Basis for Table 16

TABLE 16

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Crushed Stone, Wet Process

PLANT SIZE 180,000 METRIC TONS PER YEAR OF Crushed Stone

PLANT AGE 40 YEARS PLANT LOCATION rural location near population center

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		0	14,500	19,000	22,500	
ANNUAL CAPITAL RECOVERY		0	2,400	3,100	3,700	
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		0	6,400	6,400	7,400	
ANNUAL ENERGY AND POWER		0	1,000	2,000	2,000	
TOTAL ANNUAL COSTS		0	9,800	11,500	13,100	
COST/METRIC TON product		0	0.054	0.064	0.073	
WASTE LOAD PARAMETERS (kg/metric ton of product)	RAW WASTE LOAD					
Suspended Solids	60	60	0.2	0	0	

LEVEL DESCRIPTION:

A — direct discharge
B — settling pond, discharge
C — settling pond, recycle
D — flocculant, settling pond, recycle

Level B

Pond Cost	$10,000
Pumps and piping	4,500
Power	1,000
Pond cleaning	6,000
Taxes and insurance	400

Level C

Total pond cost	$10,000
Total pump and piping cost	9,000
Annual capital recovery	3,100
Power	2,000
Pond cleaning	6,000
Taxes and insurance	400

Level D

Additional capital flocculant equipment	$ 3,500
Additional annual capital	600
Annual chemical cost	1,000

Cost Variances

(1) Granite fines settle somewhat slower than limestone fines. As a result, recirculation granite ponds generally run about 50% larger than those of limestone for the same capacity facility.

(2) The amount of waste in the effluent is largely depended on the type of product. Six percent was chosen as an average value. Range of wastes is 2 to 12 percent. Cost to treat per ton of product is approximately proportional to percent waste.

The amount of stone washed in any given year varies with the demand for a washed product. The capital costs for treatment are more readily absorbed when a large portion of the stone is washed.

Capital costs are estimated to vary as the 0.9 power of size and operating expenses are proportional to size.

Estimation of Total Costs for Subcategory

There are an estimated 1600 facilities in this category producting an estimated 140 million kkg (150 million tons) of washed stone along with 140 million kkg (150 million tons) of dry processed stone annually. An estimated 500 of these 1600 facilities are presently on complete recycle. The remaining 1100 facilities produce approximately 91 million kkg/yr (100 million tons/yr) of stone, 50% of which is washed.

The average cost increase per ton for the wet process crushed stone industry would be $0.044 ($0.048/kkg) to convert to recycle. The capital expenditure for the same is estimated to be $10,000,000.

CRUSHED STONE, FLOTATION PROCESS

There are an estimated eight facilities in this subcategory, with a combined estimated annual production of 500,000 tons. The process is identical to that of wet crushed stone, except for an additional flotation step, using an additional 5% of process water. The wash water can be recycled as in wet processing, but the flotation water cannot be directly recycled due to the complex chemical processes involved. The two waste streams can be combined; however, and be recycled in the washing process. The flotation process would require fresh input.

Typical Facility Data

The treatment used is settling ponds and recycle. Assuming a 5% loss (equivalent to the input from flotation) from the combined effects of percolation and evaporation, discharge would be eliminated under normal conditions.

Estimation of Total Costs for Subcategory

It is estimated that two of the eight facilities in this subcategory are presently recycling their waste water. The remaining six could achieve recycle with total capital cost of $200,000. The selling price of the product is $33/kkg, ($30/ton), therefore the increase in operating cost due to recycle is approximately 0.2 percent.

CONSTRUCTION SAND AND GRAVEL

The construction sand and gravel industry has been divided into three subcategories:

(1) Dry process
(2) Wet process
(3) River dredging with on-land processing

DRY PROCESS

Typical Facility Data

A typical dry process sand and gravel facility produces 454,000 kkg/yr (500,000 tons/yr) of construction sand and gravel. There is no process water use, no non-contact cooling water and no pit pumpout.

Treatment Options

Since there is no water use or waste water generated, treatment is not required.

Cost/Benefit Analysis of Treatment Technology

There is no cost of treatment at a typical facility.

Cost Variances

Pit pumpout is required at some facilities during periods of high rainfall. Some facilities also have a non-contact cooling water discharge. The pit pumpout in some of these cases is settled in a sump or pond.

Age, location, and production have no consistent effect on waste waters from facilities in this subcategory, or on costs to treat them.

There are an estimated 750 facilities in this subcategory representing a production of 129 x 10^6 kkg/yr (143 x 10^6 tons/yr).

WET PROCESS

Typical Facility Data

The average production rate of facilities in this subcategory is 130,000 kkg/yr (143,000 tons/yr). Median facility size is approximately 227,000 kkg/yr (250,000 tons/yr). This is selected as representative for facility size.

10 percent of raw material in waste stream (68,000 mg/l)

11,400 l/min (3,000 gal/min) used for washing

all particles down to 200 mesh (74 micron) are recovered for sale by screw classifier cyclones, etc.

Cost Basis for Table 17

Level B: 5.6 acre settling pond and discharge of effluent.

Pond cost	$28,000
Pump cost	2,000
Pipe cost	3,000
Annual power	300
Taxes and insurance	800
Maintenance	800

Level C: 5.6 acre settling pond followed by recycle of waste water.

Total pond cost	$28,000
Total pump cost	3,000
Total pipe cost	6,000
Power, annual	600
Taxes and insurance	1,000
Maintenance	1,000

Level D: Two silt removal ponds of 0.04 ha (0.1 acre) each are used alternately prior to the main settling pond of 5.6 acres. The life of the main pond is greatly increased as most of the solids are removed in the primary ponds. One small pond is dredged while the other is in use. The sludge is deposited on site.

Total pond cost	$30,000
Annual pond cost	3,600
Total pump and piping	10,000
Annual pump and piping	1,600
Annual dredging and sludge disposal	20,000
Power	600
Taxes and insurance	1,000

Level E: Mechanical thickener is used along with a flocculating agent to produce an effluent of 250 mg/l for recycle. The underflow sludge is transported to a 4 acre sludge disposal basin at a cost of $1.1/kkg ($1/ton)

TABLE 17

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Construction Sand & Gravel, Wet Process

PLANT SIZE 227,000 METRIC TONS PER YEAR OF product

PLANT AGE 5 YEARS PLANT LOCATION near population center

		LEVEL						
		A (MIN)	B	C	D	E	F	G
INVESTED CAPITAL COSTS:								
TOTAL		0	33,000	37,000	40,000	50,000	180,000	21,600
ANNUAL CAPITAL RECOVERY		0	5,400	6,000	5,200	8,100	29,200	2,600
OPERATING AND MAINTENANCE COSTS:								
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		0	1,600	2,000	21,000	29,200	41,400	28,100
ANNUAL ENERGY AND POWER		0	300	600	600	400	600	400
TOTAL ANNUAL COSTS		0	7,300	8,600	26,800	37,700	71,200	31,100
COST/METRIC TON product		0	0.03	0.04	0.12	0.17	0.31	0.14
WASTE LOAD PARAMETERS (kg/metric ton of product)	RAW WASTE LOAD							
Suspended Solids	100	100	0.4	0	0	0	0	0

LEVEL DESCRIPTION:

A — direct discharge
B — settling, discharge
C — settling, recycle
D — two silt removal ponds, settling pond, recycle
E — flocculant, mechanical thickener and recycle. Transportation of sludge to disposal basin.
F — flocculant, inclined plate settlers, and recycle effluent. Transport sludge to disposal basin.
G— flocculant, settling basin, recycle

Total thickener cost	$ 18,500
Sludge disposal basin cost	20,000
Polymer feed system cost	1,600
Pump and piping	9,700

Annual sludge transportation	25,000
Annual chemical cost	2,200
Annual power	400
Maintenance	1,000
Taxes and insurance	1,000

Level F: Inclined plate settlers are used to produce an effluent of 250 mg/l which is recycled back to the process. A coagulant is added prior to the settlers to increase settling rate. The underflow sludge is transported to a 4 acre settling basin at a cost of one dollar per ton of solids. It should be noted that no case of an inclined plate settler successfully treating a sand and gravel waste was found. The advantage of this system is the small area required.

Inclined plate settler cost	$150,000
Pumping and piping	10,000
Sludge disposal basin	20,000

Sludge transportation	25,000
Chemical	2,000
Maintenance	7,200
Taxes and insurance	7,200
Power	600

Level G: Flocculant added, 1 acre settling pond is used for treatment, and effluent is recycled to the process. The sludge is dredged and deposited on site at a cost of $0.55/kkg ($0.50/ton).

Total pond cost	$ 10,000
Polymer mixing unit	1,600
Pump and piping	10,000

Chemical cost	2,200
Dredging	25,000
Power	400
Taxes and insurance	900

Cost Variances

Production. Production rate in this subcategory varies from 10,900 to 1,800,00 kkg/yr (12,000 to 2,000,000 tons/yr). Waste volume and water flow vary proportionately with production. As a result, settling area varies proportionately with production. Pond capacity also varies proportionately with sludge volume, and thus production. Pumping, piping and power costs may also be considered to be roughly proportional to water flow, and production. Thus, the capital costs for Levels B, C, D, and G are estimated to vary with size to the 0.9 power. Operating costs not related to capital are approximately proportional to size. Levels E and F use equipment for clarification rather than ponds. Capital costs for them should vary by an exponential factor of 0.7 to size. Operating costs not based on capitalization are approximately proportional to size.

Waste Content. A facility having a waste content other than ten percent should require a proportionately different water usage. The settling area required to obtain recyclable effluent should be proportional to waste content. Dredging and pumping are also proportional to waste content. Thus the treatment cost per ton of product should vary roughly proportionately with waste content. Waste content can vary from less than 5% to 30%.

Topography. A canyon or hillside can greatly reduce the cost of pond building. Also, a wet land can increase the cost of building a pond.

Particle Size. Suspended solids average particle size greater than the one shown would mean a proportionately smaller settling area would be need to produce recyclable effluent. A smaller particle size could be countered with the use of a flocculant, if necessary.

Coagulant Efficiency. An increase in settling rate would require a proportionately smaller settling area. A settling rate increase due to the use of coagulant of 100 times was assumed, based on laboratory tests and industry supplied information.

Estimated Total Costs for Subcategory

There are an estimated 4,250 facilities in the wet processing subcategory, producing 573 million tons/yr. Of these, an estimated 50% (2,125 facilities) are presently recycling their effluent. An estimated 25% of these (1,063 facilities) have no discharge under normal conditions due to evaporation and/or percolation in settling ponds. The remaining 25% (1,063 facilities) presently have a discharge. It is estimated that 90% of the facilities having a discharge (956 facilities) presently have a ponding system. These latter facilities could in most cases convert their ponds to a recycle system by installing pumps and pipe, with the use in some cases of a coagulant.

Thus the facilities in this subcategory without present ponding systems are estimated to be 2.5% (107 facilities). Almost all of these facilities could install treatment options C, D, or G, which are the least expensive. Options E or F would only be required in an urban environment where sufficient settling area is not available on site.

The 956 facilities with settling pond discharges produce an estimated 168 million tons/yr.

The installation of a pump and piping system, and the addition of a flocculant would result in a total annual cost per ton of $0.018 per ton, or the total capital expenditure required represents about 7.4 million dollars.

The 107 facilities which are presently discharging without treatment produce an estimated 18 million tons/yr. It is assumed that these facilities may achieve recycle for an average annualized cost of $0.10/ton. It should be noted that a small fraction of these 107 facilities have no land for settling ponds, and that no sand and gravel facility utilizing options E or F (no ponds) to achieve recycle was found.

Seventy-five percent of the facilities in this subcategory presently are on recycle, or have no point source discharge. 23.5% of the facilities are not on recycle but have ponds. They require a total capital expense of 7.4 million dollars, and an annualized cost of $0.018 per ton.

The facilities not having any ponds could achieve recycle for a capital cost of 1.7 million dollars. The annualized increase in production costs would average $0.10/ton.

The entire subcategory of wet processed sand and gravel could eliminate discharge of process effluent for a total capital expense of about 10 million dollars. The average cost of production would rise $0.017/ton. This price rise represents an average rise of 0.6 percent assuming an average selling price of $3 per ton.

RIVER DREDGING, ON-LAND PROCESS

Typical Facility Data

Production: 360,000 kkg/yr (400,000 tons/yr)

Assume same treatment options as in wet process facility. Costs of waste water treatment for the typical facility can be derived from these presented in Table 17 by applying the appropriate size factors.

Cost Variances

Factors affect treatment and costs in the same manner as described for wet processing.

Estimated Total Costs for Subcategory

There are an estimated fifty river dredging operations with on-land processing, producing 16,700,000 tons/yr of sand and gravel. An estimated 50% of the facilities producing 50% of the volume have no point source discharge at this time. It is estimated that twenty-two of the remaining twenty-five facilities have settling ponds at the present time. Recycle should be achievable with the aid of a flocculant for an increased production cost of $0.02/kkg ($0.018/ton).

The total capital cost for the subcategory is estimated to be $1,500,000. The average increase in production costs would be $0.01 per ton. This represents an average production cost increase of 0.3% based on an average selling price of $3 per ton.

INDUSTRIAL SAND

The industrial sand industry was divided into four subcategories:

(1) Dry process
(2) Wet process
(3) Acid and alkaline flotation
(4) HF flotation.

DRY PROCESSING

Approximately 10 percent of the industrial sand operations fall into this subcategory. The only water involved comes from dust collectors used by some facilities. Of the five dry process facilities surveyed, two have such scrubbers - one without treatment and the other with pond settling and complete recycle.

Cost For Dry Process Scrubber Water Treatment

Treatment is by addition of 5 mg/l flocculating agent and recycle through a one acre settling pond.

Assumptions:

167,000 l/day (44,000 GPD) scrubber water
5 days/week; 8 hours/day
flocculant cost - $1/lb
piping cost - $1/inch diam/linear foot
pump cost - $1/HP/yr
power cost - $.02/kwh
pond cost - $10,000/acre
TSS in raw waste - 30,000 mg/l
pond cleaning - $0.5/ton of sludge

Capital Costs:

pond	$10,000
piping and pump	3,000
polymer mixing unit	1,500
total capital	14,500
annual capital recovery	2,360

Operating Costs:

pond cleaning	$ 700
power	150
chemical	50
maintenance	725
taxes and insurance	290
total annual operating	1,700
total annual recycle costs	4,000

WET PROCESS

The wet process uses washing and screening operations similar to those for construction sand and gravel. Treatment of the waste water also used the same technologies. By use of ponds, thickeners and clarifiers, three out of the four wet process facilities studies have no discharge of process water. Table 18 summarizes the costs for two treatment technologies.

Cost Basis for Table 18

Level A: 39 acre settling pond, discharge effluent

pond cost	$60,000
pump cost	3,000
piping cost	6,000

Level B

Capital Costs

settling pond area	39 acres
pond cost	$60,000
pump costs	6,000
piping costs	13,500
total capital	$79,500

Annual Investment Costs

pond costs (20 yr life @ 10% interest) = 7000
pump costs (5 yr life @ 10% interest) = 1500
piping costs (10 yr life @10% interest) = 2200
total 10,700

TABLE 18

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Industrial Sand, Wet Process

PLANT SIZE 180,000 METRIC TONS PER YEAR OF product

PLANT AGE 10 YEARS PLANT LOCATION near population center

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		69,000	79,500	155,000		
ANNUAL CAPITAL RECOVERY		8,000	10,700	25,200		
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		2,800	3,200	21,900		
ANNUAL ENERGY AND POWER		1,000	2,000	2,000		
TOTAL ANNUAL COSTS		11,800	15,900	49,100		
COST/METRIC TON product		0.07	0.09	0.26		
WASTE LOAD PARAMETERS (kg/metric ton of product)	RAW WASTE LOAD					
Suspended Solids	35	0.7	0	0		

LEVEL DESCRIPTION:

A — settle, discharge

B — settle, recycle

C — mechanical thickener with coagulant, overflow is recycled to process. Underflow is passed through a settling basin. Effluent from the settling basin is also recycled to process.

Operating Costs

maintenance costs @ 2% of capital	=	1600
power cost @ $.02 per kwh	=	2000
taxes and insurance @ 2% of capital	=	1600
total		$5200

Level C

Capital Costs

settling pond area	-	39 acres
pond costs	-	60,000
polymer feed system	-	5,000
thickener	-	60,000
pump costs	-	15,000
piping costs	-	15,000
total		155,000

total annual capital costs (10 years @ 10%) = $25,200

Operating Costs

chemicals	11,000
maintenance @ 5% of capital	7,800
power	2,000
taxes and insurance @ 2% of capital	3,100
total	23,900

Cost Variances

Age. Facilities surveyed for this subcategory have ages from one to 20 years. There is no discernable correlation of treatment costs with facility age.

Location. There was no discernable correlation of waste water treatment costs with location.

Size. Production capacities range from 54,000 to 900,000 kkg/yr (60,000 to 1,000,000 tons/yr). Treatment technology Levels A and B, involving pond costs, should show slight unit cost variation (0.9 power). Level C technology with a mechanical thickener as well as a pond are estimated to be 0.7 exponential function of size. Operating costs other than taxes, insurance and annualized capital costs are estimated to be proportional to size.

ACID AND ALKALINE FLOTATION

There are three types of flotation processes used for removing impurities from industrial sands:

(1) Acid flotation to effect removal of iron oxide and ilmenite impurities

(2) Alkaline flotation to remove aluminate bearing materials, and

(3) Hydrofluoric acid flotation for removal of feldspar.

These three flotation processes have been subdivided into two subcategories; (1) acid and alkaline flotation and (2) hydrofluoric acid flotation. Subcategory (1) is discussed in this subsection and subcategory (2) in the following subsection.

Four surveyed acid flotation facilities have no effluent discharge. The surveyed alkaline flotation facility has effluent waste water similar in composition to the intake stream. Recycle costs for acid and alkaline flotation waste water are given in Table 19.

Cost Basis For Table 19

Basis: (1) production - 180,000 kkg/yr (200,000 tons/yr)
(2) the process waste water is treated with lime, pumped to a holding pond and recirculated back to the facility. The holding pond is one-half acre and is cleaned once every ten years.

Capital Costs

lime storage and feed system	-	75,000
reaction tank	-	40,000
pumps and piping	-	20,000 agent

annualized capital cost (10 yr life @ 10%)	22,000

Operating Costs

chemical costs	-	11,000
maintenance @ 5% of capital	-	7,300
power	-	2,000
taxes and insurance @ 2% of capital	-	2,900
total		23,200

TABLE 19

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Industrial Sand (acid and alkaline flotation)

PLANT SIZE 180,000 METRIC TONS PER YEAR OF product

PLANT AGE 30 YEARS PLANT LOCATION southeastern U.S.

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		115,000	135,000			
ANNUAL CAPITAL RECOVERY		18,700	22,000			
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		19,000	21,200			
ANNUAL ENERGY AND POWER		1,000	2,000			
TOTAL ANNUAL COSTS		38,700	45,200			
COST/METRIC TON product		0.22	0.25			
WASTE LOAD PARAMETERS (kg/metric ton of product)	RAW WASTE LOAD					
Suspended Solids	100	0.4	0			

LEVEL DESCRIPTION:

A — neutralize, settle, discharge
B — neutralize, settle, recycle

Cost Variances

Age. Surveyed facilities in this subcategory ranged in age from one to 60 years. There was no discernable correlation between treatment costs and facility age.

Location. Most of the surveyed facilities are in southeastern U.S. There was no discernable correlation between treatment costs and facility location.

Size. Facilities in this subcategory range between 19,000 to 1,360,000 kkg/yr (54,000 to 1,500,000 tons/yr). Costs/acre of small ponds change significantly with size. Also, the chemical treatment facilities costs vary with size at an estimated exponential rate of 0.6. Taken together, capital costs are estimated to vary with size at 0.7 exponential rate. Operating costs, except for taxes, insurance and other capital related factors may be expected to vary directly with size.

HF FLOTATION

Unlike the acid and alkaline flotation processes where total recycle is either presently utilized or believed to be feasible, on the other hand, waste water from the HF flotation process is of questionable quality for total recycle. Estimated costs for partial recycle are given in Table 20.

Cost Basis For Table 20

Basis: (1) production: 180,000 kkg/yr (200,000 tons/yr)
(2) all waste waters are fed to a thickener to remove suspended materials. The overflow containing 90 percent of the water is recycled to the process, the underflow is fed to a settling pond for removal of solid wastes and pH adjustment prior to discharge.

TABLE 20

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Industrial Sand (HF Flotation)

PLANT SIZE 180,000 METRIC TONS PER YEAR OF product

PLANT AGE -- YEARS PLANT LOCATION California

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		120,000	200,000			
ANNUAL CAPITAL RECOVERY		19,500	32,500			
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		21,400	21,400			
ANNUAL ENERGY AND POWER		2,000	2,000			
TOTAL ANNUAL COSTS		42,900	55,900			
COST/METRIC TON product		0.23	0.31			
WASTE LOAD PARAMETERS (kg/metric ton of product)	RAW WASTE LOAD					
Suspended Solids	135	0.044	0			
Fluoride	0.45	0.005	0			

LEVEL DESCRIPTION:

A — 90% of wastewater removed in thickener and recycled to process. Underflow from thickener fed to settling pond for removal of tailings and pH adjustment prior to discharge.

B — segregate HF waste water, pond and evaporate; recycle other water after ponding.

Capital Costs

pond - 1/2 acre x 10 ft depth @ $20,000/acre	=	$ 10,000
lime storage and feed system	=	30,000
thickener	=	60,000
pump costs	=	5,000
piping costs	=	15,000
total		120,000

annualized investment costs (10 yr life @ 10% interest)

$120,000 x .1629 = $19,500

Operating Costs

maintenance @ 5% of capital	=	6,000
chemicals, lime @ $20/ton	=	11,000
power @ $.02/kwh	=	2,000
taxes and insurance @ 2% of capital	=	2,400
total		23,400

Cost Variances

Age, location and size variances have no significance in this case since only one facility is involved.

GYPSUM

Gypsum is mined at sixty-five sites in the United States. An estimated 57 of these facilities use no contact water in their process. It is estimated that 5 of the facilities use wet scrubbers for dust removal, which results in a contact water effluent. Two known facilities use heavy media separation and washing to beneficiate the crude gypsum ore, which results in a process effluent.

DRY PROCESS

There is no contact process water in this category, thus there are no waste water treatment costs.

DRY PROCESS WITH USE OF WET SCRUBBERS

There are five facilities in this subcategory. Two are presently using settling ponds. All five intend to install dry scrubbers at some time in the future.

The scrubber water usage in two facilities in this subcategory averages 2,505 l/kkg (598 gal/ton) of gypsum produced. The effluent quality from these two facilities averages 35 mg/l with a pH of 7.8. One of the two facilities impounds the water before discharge while the second discharges without treatment. Present waste water treatment costs for both are considered to be negligible. The capital cost of a settling pond for such facilities is $20,000.

A third facility in this subcategory uses 5,950 l/kkg (1,427 gal/ton) of scrubber water with a suspended solids concentration of 1,110 mg/l. This represents a substantial increase in water usage and suspended solids load over the previous two facilities. Present treatment consists of a settling pond which removes fifty percent of the suspended solids. The total annual cost for the settling pond was reported as $2,500, which results in a cost of $0.01 per kkg of gypsum produced. The company plans to replace the wet scrubber system with a dry dust collector, which would eliminate the waste stream. The capital investment for the dry system was reported as $167,000. The annual capital recovery for such a system would be $27,200 which results in a cost of $0.14 per kkg of gypsum produced ($0.13/ton). All gypsum producers contacted which use wet scrubbers indicated that they plan to convert their systems to dry dust collectors.

HEAVY MEDIA SEPARATION

The third subcategory of wet processing of gypsum consists of only two facilities. Both facilities presently have effluent due to recycle of water after settling pond treatment. In one of the facilities an abandoned mine is utilized as the settling pond. Capital investment for the system is estimated to be $15,000. Annual operating cost is estimated to be $10,000. Total annualized recycle costs are estimated to be $12,500. This results in a recycle cost of $0.05 per kkg of gypsum produced ($0.045/ton).

MINE DRAINAGE

In all three of the subcategories of gypsum production, some facilities find it necessary to pump out their quarries because of rainwater collection. No facility is presently treating its mine pumpout water, and the average effluents are all below 25 mg/l, insofar as is known, so there is no cost to treat the pit pumpout in this subcategory down to this level, at least.

ASPHALTIC MINERALS

Of the asphaltic minerals, bituminous limestone, oil-impregnated diatomite and gilsonite, only gilsonite operations currently have any discharge to surface water.

For gilsonite, present mine water drainage treatment consists of pond settling of suspended solids prior to discharge. Process water is discharged untreated. Costs for present treatment are an estimated $0.08/kkg of gilsonite produced ($0.07/ton).

Completion of treatment facilities currently under construction will result in no discharge of waste water from the property at a cost of $1.10/kkg ($1/ton) of Gilsonite produced. The cost estimates are given in Table 21.

Cost Variances

The only gilsonite facility is 50 years old and located in Utah. All cost developments are for this specific facility.

Cost Basis For Table 21

Level A

Capital Costs

pond cost, $/hectare ($/acre): $24,700 ($10,000)
settling pond area, hectares (acres): 0.8 (2)
pump, piping, ditching: $5,000

Operating and Maintenance Costs

taken as 2% of capital costs

Level B

Capital Costs

pond costs - same as Level A	
sand filters -	$150,000
pumps and piping -	40,000
electrical and instrumentation	25,000
roads, fences, landscaping -	15,000

TABLE 21

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Gilsonite

PLANT SIZE 45,450 METRIC TONS PER YEAR OF Gilsonite

PLANT AGE 50 YEARS PLANT LOCATION Utah

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		25,000	250,000			
ANNUAL CAPITAL RECOVERY		2,940	29,400			
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		500	20,000			
ANNUAL ENERGY AND POWER		200	500			
TOTAL ANNUAL COSTS		3,640	49,900			
COST/METRIC TON Gilsonite		0.08	1.10			
WASTE LOAD PARAMETERS	RAW WASTE LOAD					
Mine Pumpout:						
Suspended Solids, mg/liter		3,375	0			
BOD, mg/liter		12	0			
Process Water:						
Suspended Solids, mg/liter		17	0			
BOD, mg/liter		43	0			

LEVEL DESCRIPTION:

A — pond settling of suspended solids in mine pumpout; no treatment of process water (present minimum).

B — combining of mine pumpout and process water followed by pond settling, filtration and partial recycle. Discharge from recycle to be used for on-property irrigation.

Operating and Maintenance Costs

labor - 1/2 man @ $10,000/yr	$ 5,000
maintenance labor and materials @ 4% of investment	10,000
power @ $.01/kw-hr	500
taxes and insurance @ 2% of investment	5,000

ASBESTOS

Asbestos is mined and processed at five locations in the U.S., two in California, and one each in Vermont, Arizona and North Carolina. One facility in California uses a wet processing process, while the remaining four facilities use a dry process. There is also one wollastonite dry facility which has no process water. The wet process facility process results in a discharge of twenty percent of the process water (155,200 l/day; 41,000 gal/day) to two percolation/evaporation ponds. The ponds total less than one half acre in size. The total capital investment for the percolation ponds was estimated to be $2,000. Annual operating and maintenance is estimated to be $1,000. The total annualized cost is estimated to be $1,325, for the percolation/evaporation ponds. One pond serves as an overflow for the other, therefore, surface water discharge almost never occurs. The ponds are dredged once annually.

Sixty-eight percent of the water in the wet process facility is recycled via a three acre settling pond. A natural depression is utilized for the pond, and dredging has been not necessary. The water recirculated amounts to 529,900 l/day (140,000 gal/day). Annualized cost for the recirculation system is estimated to be $2,500. The remaining twelve percent of the process water is lost in the product and tailings. Total annualized water treatment costs for wet processing of asbestos are estimated to be $3,825, which results in a cost of $0.09/kkg of asbestos produced ($0.08/ton).

All five operations accumulate waste asbestos tailings at both facility and the mining site. These tailings are subject to rainwater runoff. At two sites dams have been built to collect rainwater and create evaporation/percolation ponds. The total capital investment at each site is estimated to be $500. Operating and maintenance costs for these dams are considered to be negligible. Natural canyons were utilized in both cases to create the ponds. One facility because of its geological location must discharge water collected in its mine. The alkaline groundwater in the area requires the water to be treated by addition of 0.02 mg/l sulfuric acid before discharge. The pumping costs for this operation are considered to be part of the production process. The chemical costs are considered to be less than $100/yr. The total waste water treatment costs for pit pumpout water are therefore considered to be negligible. The estimated capital cost for total impoundment of mine water to eliminate the discharge is $15,000.

LIGHTWEIGHT AGGREGATE MINERALS

Lightweight aggregate minerals consist of perlite, pumice and vermiculite.

PUMICE

All U.S. perlite facilities are in southwestern U.S. and the processes are all dry. Since there is no water used, there is no waste water generated or water treatment required. One investigated mine does dewater the quarry when water accumulates, but this water is evaporated on land at estimated cost of $0.01 to $0.05/kkg (or ton) of perlite produced.

PERLITE

At most facilities, there are no waterborne wastes as no water is employed. At one facility there is scrubber water from a dust control installation. The scrubber water is sent to a settling pond prior to discharge. Because of the relatively small amount of water involved and the large production volume of pumice per day, treatment costs for this one facility are roughly estimated as less than $0.05/kkg (or ton) of pumice produced at that facility.

VERMICULITE

The two facilities described in Section V represent total capacity appraching the total U.S. production. Both of these facilities currently achieve no discharge of pollutants by means of recycle, pond evaporation and percolation. Detailed costs for a typical facility are given in Table 22.

Cost Variance

Age. The ages of the two facilities are 18 and 40 years. Age is not a cost variance factor.

Location. One facility is located in Montana and the other in South Carolina. In spite of their different geographical location, both are able to achieve no discharge of pollutants by the same general means and at roughly equivalent costs.

Size. Facility sizes range from 109,000 to 209,000 kkg/yr (120,000 to 230,000 tons/yr). Since pond costs per acre are virtually constant in the size range involved, waste water treatment costs may be considered directly proportional to facility size and therefore invariant on a cost/ton of product basis.

TABLE 22

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Vermiculite

PLANT SIZE 160,000 METRIC TONS PER YEAR OF product

PLANT AGE 30 YEARS PLANT LOCATION Montana or South Carolina

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		325,000				
ANNUAL CAPITAL RECOVERY		52,900				
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		40,000				
ANNUAL ENERGY AND POWER		5,000				
TOTAL ANNUAL COSTS		97,900				
COST/METRIC TON product		0.62				
WASTE LOAD PARAMETERS (kg/metric ton of product)	RAW WASTE LOAD					
Suspended Solids	1,600	0				

LEVEL DESCRIPTION:

A — recycle, evaporation and percolation.

Cost Basis For Table 22

Capital and operating costs were taken from industry reported values. The basis of these values is shown below:

Assumptions:

Production:	157,000 kkg/yr (175,000 tons/yr)
Process Water Use:	8,350 l/kkg (2,000 gal/ton)
Treatment:	settling ponds and recycle of process water
Capital Cost:	$325,000
Operating Costs:	$ 45,000/yr
Annual Capital Recovery:	$ 52,900

MICA

There are seven significant wet mica beneficiation facilities in the U.S., six dry grinding facilities processing beneficiated mica, and three wet grinding facilities.

There are also several western U.S. operations using dry surface mining. They have only some mine water drainage. Treatment for this mine water is estimated as $0.19/kkg ($0.2/ton) (based on a 1/2 acre pond @ $10,000/acre and operating costs of $750/yr).

WET BENEFICIATION PLANTS

Eastern U.S. beneficiation facilities start with matrices of approximately 10 percent mica and 90 percent clay, sand, and feldspar combinations. Much of this 90 percent is converted to saleable products, but there is still a heavy portion which must be stockpiled or collected in pond bottoms. The variable nature of the ore, or matrix, leads to several significant treatment/cost considerations:

(1) Treatment costs and effluent quality differ from facility to facility.

(2) Additional saleable products reduce the cost impact of the overall treatment systems developed.

(3) Solids disposal costs are often a major portion of the overall treatment costs, particularly if they have to be hauled off the property.

All of these factors can change the overall treatment costs per unit of product of Table 23 by at least a factor of two in either direction.

Cost Variances

Age. Known ages for four of the seven facilities range from 18 to 37 years. There is no significant treatment cost variance due to this range.

Location. All facilities are located in southeastern states in rural locations. Location is not a significant cost variance factor.

Size. The sizes range from 13,600 to 34,500 kkg/yr (1,500 to 3,800 tons/yr). The unit costs given are meant to be representative over this size range on a unit production basis.

TABLE 23

COST FOR A REPRESENTATIVE PLANT

(ALL COSTS ARE CUMULATIVE)

SUBCATEGORY Mica, Wet Beneficiation (eastern)

PLANT SIZE 16,360 METRIC TONS PER YEAR OF Mica

PLANT AGE 27 YEARS PLANT LOCATION Southeastern U.S.

		LEVEL				
		A (MIN)	B	C	D	E
INVESTED CAPITAL COSTS:						
TOTAL		150,000	275,000	300,000	245,000	245,000
ANNUAL CAPITAL RECOVERY		17,600	32,300	35,200	39,900	39,900
OPERATING AND MAINTENANCE COSTS:						
ANNUAL O & M (EXCLUDING POWER AND ENERGY)		50,000	64,500	68,000	74,400	74,400
ANNUAL ENERGY AND POWER		2,000	3,000	5,000	5,000	5,000
TOTAL ANNUAL COSTS		69,600	99,800	108,200	119,300	119,300
COST/METRIC TON Mica		4.3	6.1	6.6	7.3	7.3
WASTE LOAD PARAMETERS (kg/metric ton of Mica)	RAW WASTE LOAD					
Suspended Solids	2,100	2.5-6	1.2-2.5	0	1.2-2.5	0
pH	--	6-9	6-9	-	6-9	-

LEVEL DESCRIPTION:

A — minimum level ponding
B — extended ponding and chemical treatment
C — closed cycle pond system (no discharge)
D — mechanical thickener and filter
E — closed cycle thickener and filter system (no discharge)

Cost Basis For Table 23

Treatment Level A - Pond settling of process wastes (minimum treatment)

Basis: (1) Production rate - 16,400 kkg/yr (18,000 ton/yr)

(2) Solid wastes ponded - 34,200 kkg/yr (38,000 ton/yr)

(3) Solid waste stockpiled - 45,000 kkg/yr (50,000 ton/yr)

(4) Pond size - 4 hectares (10 acres)

(5) Effluent quality
  (a) suspended solids - 20-50 mg/l
  (b) pH - 6-9

(6) Waste water effluent - 5.7 x 10^6 l/day (1.5 mgd)

Capital Costs

Ponds	=	$100,000
Pumps and piping	=	35,000
Miscellaneous constructions	=	15,000
Total	=	$150,000

Assume 20 yr life and 10% interest
capital recovery factor = .1174

Annual investment costs = $17,610/yr

Operating Costs

Solid wastes handling @ $0.30/ton	=	$15,000
Pond cleaning @ $0.50/ton	=	19,000
Maintenance	=	10,000
Power	=	2,000
Labor	=	3,000
Taxes and insurance @ 2% of capital	=	3,000
Total		$52,000

Treatment Level B - Pond settling of process wastes and chemical treatment

Basis: Same as for Level A, except

(1) Pond size - 8 hectares (20 acres)
(2) Chemical treatments - lime, acid and flocculating agents used as needed
(3) Effluent quality
    (a) suspended solids - 10-20 mg/l
    (b) pH - 6-9

Capital Costs

Ponds	=	$200,000
Pumps and piping	=	50,000
Miscellaneous construction	=	25,000
Total		$275,000

Annual investment costs = $32,285/yr

Operating Costs

Solid wastes handling @ $0.30/ton	=	$15,000
Pond cleaning @ $0.50/ton	=	19,000
Maintenance	=	15,000
Chemicals	=	5,000
Power	=	3,000
Labor (misc)	=	5,000
Taxes and insurance @ 2% of capital	=	5,500
Total		$67,500

Treatment Level C - Total recycle of process water using pond system

Basis: Same as Level B except no discharge

Capital Costs

Ponds	=	$200,000
Pumps and piping	=	75,000
Miscellaneous construction	=	25,000
Total		$300,000

Annual investment costs = $35,220

Operating Costs

Solids wastes handling @ $0.30/ton = $15,000
Pond cleaning @ $0.50/ton = 19,000
Maintenance = 20,000
Chemicals = 5,000
Power = 5,000
Labor = 3,000
Taxes and insurance @ 2% of capital = 6,000
Total $73,000

Treatment Level D - Thickener plus filter removal of suspended solids. Generally pond systems are the preferred system for removing suspended solids from waste water. In some instances, however, when the land for ponds is not available or there are other reasons for compactness, mechanical thickeners, clarifiers, and filters are used.

Basis: Same as for Level B, except no pond required

Capital Costs

Thickener - 15 meter (50 ft.) diameter = $150,000
Filter system installed = 35,000
Pumps, tanks, piping, collection = 50,000
Conveyor = 5,000
Building = 5,000
Total $245,000

At 10 yr life and 10% interest rate
Capital recovery factor = .1627
Annual investment costs = $39,862

Operating Costs

Solids wastes handling @ $0.30/ton = $26,400
Maintenance = 20,000
Chemicals = 20,000
Power = 5,000
Labor = 3,000
Taxes and insurance @ 2% of capital = 5,000
Total $79,400

Treatment Level E - Thickener and filter removal of suspended solids and recycle to eliminate discharge.

Basis: Same as for Level D, complete recycle of treated wastes

Capital Costs

Same as for Level D - pumping and piping to surface water discharge taken as same as recycle piping and pumping.

Operating Costs

Same as for Level D
Total annual costs = $119,300

DRY GRINDING PLANTS

There are no waterborne wastes from this subcategory.

WET GRINDING PLANTS

Of the three facilities involved, one sends its small amount of waste water to nearby waste treatment facilities of much larger volume, the second has no waterborne waste due to the nature of its process and the third uses a settling pond to remove suspended solids prior to water recycle. Total costs for waste water treatment from this third operation are estimated as $2.60/kkg of wet ground mica produced ($2.30/ton). A capital investment of $65,000 is required.

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1977, are based on the degree of effluent reduction attainable through the application of the best practicable control technology currently available. For the mining of minerals for the construction industry, this level of technology was based on the average of the best existing performance by facilities of various sizes, ages, and processes within each of the industry's subcategories. In Section IV, this segment of the minerals mining and processing industry was divided into nine major categories. Several of these major categories have been further subcategorized and, for reasons explained in Section IV, each subcategory will be treated separately for the recommendation of effluent limitations guidelines and standards of performance.

Best practicable control technology currently available emphasizes treatment facilities at the end of a manufacturing process but also includes the control technology within the process itself when it is considered to be normal practice within an industry. Examples of waste management techniques which were considered normal practice within these industries are:

(a) manufacturing process controls;
(b) recycle and alternative uses of water; and
(c) recovery and/or reuse of some waste water constituents.

Consideration was also given to:

(a) the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;
(b) the size and age of equipment and facilities involved;
(c) the process employed;
(d) the engineering aspects of the application of various types of control techniques;
(e) process changes; and
(f) non-water quality environmental impact (including energy requirements).

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The following is a discussion of the best practicable control technology currently available for each of the subcategories, and the proposed limitations on the pollutants in their effluents.

GENERAL WATER GUIDELINES

Process Water

Process water is defined as any water contacting the ore, processing chemicals, intermediate products, by-products or products of a process including contact cooling water. All process water effluents are limited to the pH range of 6.0 to 9.0 unless otherwise specified.

Process generated waste water is defined as any water which in the mineral processing operations such as crushing, washing and beneficiation, comes into direct contact with any raw material, intermediate product, by-product or product used in or resulting from the process.

Where sufficient data was available a statistical analysis of the data was performed to determine a monthly and a daily maximum. In most subcategories, where there is an allowable discharge, an achievable monthly maximum was determined from the data available.

A detailed analysis of the ratio of daily TSS to monthly TSS maximum at a 99 percent level of confidence for large phosphate slime ponds indicates that a TSS ratio of 2.0 is representative of a large settling pond treatment system, and this ratio was used where there was insufficient data to predict a daily maximum directly.

A ratio of 2.0 was also used for parameters other than TSS. It is judged that this is an adequate ratio since the treatment systems for F, Zn and Fe for instance have controllable variables, such as pH and amount of lime addition. This is in contrast to a pond treating only TSS which has few if any operator controllable variables.

Cooling Water

In the minerals mining and processing industry, cooling and process waters are sometimes mixed prior to treatment and discharge. In other situations, cooling water is discharged separately. Based on the application of best practicable technology currently available, the recommendations for the discharge of such cooling water are as follows:

An allowed discharge of all non-contact cooling waters provided that the following conditions are met:

(a) Thermal pollution be in accordance with EPA standards. Excessive thermal rise in once through non-contact cooling water in the mineral mining industry has not been a significant problem.

(b) All non-contact cooling waters should be monitored to detect leaks of pollutants from the process. Provisions should be made for treatment to the standards established for process waste water discharges prior to release in the event of such leaks.

(c) No untreated process waters be added to the cooling waters prior to discharge.

The above non-contact cooling water recommendations should be considered as interim, since this type of water plus blowdowns from water treatment, boilers and cooling towers will be regulated by EPA as a separate category.

Mine Drainage

Mine drainage is any water drained, pumped or siphoned from a mine.

Storm Water Runoff

Untreated overflow may be discharged from process waste water or mine drainage impoundments without limitation if the impoundments are designed, constructed and operated to contain all process generated waste water or mine drainage and surface runoff into the impoundments resulting from a 10 year 24 hour precipitation event as established by the National Climatic Center, National Oceanic and Atmospheric Administration for the locality in which such impoundments are located. To preclude unfavorable water balance conditions resulting from precipitation and runoff in connection with tailing impoundments, diversion ditching should be constructed to prevent natural drainage or runoff from mingling with process waste water or mine drainage.

WASTE WATER GUIDELINES AND LIMITATIONS

DIMENSION STONE

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of dimension stone is ponding and recycle of process water. To implement this technology at facilities not already using the recommended control techniques would require the improvement of suspended solids settling and the installation of recycle equipment. At least seven facilities representing all the major types of stone presently achieve the recommended limits. Four facilities were cited in Section V as applying total recycle of process waste water.

CRUSHED STONE (DRY)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated generated waste water pollutants because no process water is used.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

CRUSHED STONE (WET)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of crushed stone by the wet process is recycle of process waste water. To implement this technology at facilities not already using the recommended control techniques would require the installation of pumps and associated recycle equipment. Approximately one third of the facilities studied presently use the recommended technology.

CRUSHED STONE (FLOTATION PROCESS)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of crushed stone by the flotation process is recycle of all process water to the wet process washing step. To implement this technology at facilities not already using the recommended control techniques would require the installation of pumps and associated recycle equipment. This technology is already employed in at least two facilities in this subcategory.

CONSTRUCTION SAND AND GRAVEL (DRY)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaiminated runof.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

CONSTRUCTION SAND AND GRAVEL (WET)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of construction sand and gravel by the wet process is ponding and/or recycle of all process waste water. To implement this technology at facilities not already using the recommended control techniques would require installation of ponds where necessary and plumbing and piping for recycling. More than half the subcategory is presently using the recommended technologies.

CONSTRUCTION SAND AND GRAVEL (DREDGING WITH LAND PROCESSING)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants from the land based operations where the process water intake does not originate from the dredge pump. No limits are proposed for dredges and dredge pumpage water pending further investigation of this subcategory.

Based upon the data in Section V the following limits can be achieved for process contaiminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of construction sand and gravel by the dredging process with land processing is ponding and/or recycle of all non-dredge pumped process waste water.

To implement this technology at facilities not already using the recommended control techniques would require installation of ponds, if necessary, and pumping and piping for recycling.

More than half this subcategory is presently achieving this level of technology for on-land treatment.

INDUSTRIAL SAND (DRY PROCESS)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of industrial sand by the dry process is the recycle of air pollution control scrubber water, where wet scrubbers are used. There is no water used in the processing of this mineral. To implement this technology at facilities not already using the recommended control techniques would require the installation of pumps, piping, and tanks for scrubber recycle, where wet scrubbers are used. This technology is employed by at least one facility in this subcategory.

INDUSTRIAL SAND (WET PROCESS)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of industrial sand by the wet process is settling of suspended solids by means of mechanical equipment and/or ponds and complete recycle of process water. To implement this technology at facilities not already using the recommended control techniques would require the installation of adequate settling equipment and/or ponds and recycle equipment. Three of the four facilities surveyed presently utilize the recommended technologies.

INDUSTRIAL SAND (ACID AND ALKALI FLOTATION PROCESS)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of industrial sand by the acid and alkali flotation processes is the settling of suspended solids in ponds using flocculants where necessary, adjustment of pH where necessary and/or recycle of process water. To implement this technology at facilities not already using the recommended control techniques would require the installation of pumps, piping and other necessary recycle equipment. Four of the five facilities studied are currently meeting the recommended limitation by utilizing these technologies.

INDUSTRIAL SAND (HF FLOTATION PROCESS)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is:

Effluent Characteristic	Effluent Limitation kg/kkg (lb/1000 lb) of product Monthly Average	Daily Maximum
TSS	0.044	0.088
fluoride	0.005	0.01

The above limitations were based on the average performance of the only facility in this subcategory.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of industrial sand by the HF flotation process is thickening, ponding to settle suspended solids, pH adjustment and partial recycle of process water. The only facility in this subcategory presently uses the recommended technologies.

GYPSUM (DRY)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

GYPSUM (WET SCRUBBING)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is:

Effluent Characteristic	Effluent Limitation kg/kkg of product Monthly Average	Daily Maximum
TSS	0.13	0.26

The above limitations were based on the performance demonstrated at facilities employing wet scrubbers for dust collection.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of gypsum using wet scrubbing is settling of suspended solids by ponds or mechanical equipment. To implement this technology at facilities not already using the recommended control techniques would require the installation of solids settling equipment or ponds.

This technology is already employed by facilities in this subcategory.

GYPSUM (HEAVY MEDIA SEPARATION)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of gypsum by the heavy media separation process is recovery of heavy media, settling of suspended solids, and total recycle of process water. This technology is used at both facilities in this subcategory.

ASPHALTIC MINERALS (BITUMINOUS LIMESTONE)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process waste water is used.

ASPHALTIC MINERALS (OIL IMPREGNATED DIATOMITE)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Best practiclable control technology currently available for the mining and processing of oil impregnated diatomite is the recycle of scrubber water. There is no water used in the processing of this material.

The one facility in this subcategory presently uses the recommended technology.

ASPHALTIC MINERALS (GILSONITE)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Best practicable control technology currently available for the mining and processing of gilsonite is ponding, settling and partial recycle of water.

There is only one facility in this subcategory and this facility presently uses the recommended technologies.

ASBESTOS (DRY PROCESS)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants because no water is used in the process.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

ASBESTOS (WET)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of asbestos by the wet process is total impoundment of all process waste waters.

The techniques described are currently used by the only facility in this subcategory.

WOLLASTONITE

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

LIGHTWEIGHT AGGREGATE MINERALS (PERLITE)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used.

LIGHTWEIGHT AGGREGATE MINERALS (PUMICE)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used.

LIGHTWEIGHT AGGREGATE MINERALS (VERMICULITE)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Best practicable control technology currently available for the mining and processing of vermiculite is ponding to settle suspended solids, clarification with flocculants if needed, and recycle of water to process.

The two major facilities producing vermiculite presently use the recommended technologies.

MICA AND SERICITE (DRY PROCESS)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants because no process water is used.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

MICA (WET GRINDING PROCESS)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of mica by the wet grinding process is settling of suspended solids and recycle of clarified water to process. To implement this technology at facilities not already using the recommended control techniques would require the installation of settling tanks and/or ponds and recycle equipment. One of the three facilities in this subcategory utilizes the recommended technologies.

MICA (WET BENEFICIATION PROCESS, EITHER NON-CLAY OR GENERAL PURPOSE CLAY BY-PRODUCT)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of mica by the wet beneficiation process where either no clay or general purpose clay is the by-product is settling of suspended solids in ponds and recycle of process water. Four of the five facilities in this subcategory are presently using the recommended technologies.

MICA (WET BENEFICIATION PROCESS, CERAMIC GRADE CLAY BY-PRODUCT)

Based upon the information contained in Sections III through VIII, a determination has been made that the degree of effluent reduction attainable through the application of the best practicable control technology currently available is:

Effluent Characteristic	Effluent Limitation kg/kkg of product (lbs/1000 lb) Monthly Average	 Daily Maximum
TSS	1.5	3.0

The above limitations are based on the performance of two facilities.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best practicable control technology currently available for the mining and processing of mica by the wet beneficiation process where ceramic grade clay is the by-product is settling of suspended solids in ponds and lime treatment for pH adjustment prior to discharge. Both facilities in this subcategory are presently using the recommended technologies.

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

INTRODUCTION

The effluent limitations which must be achieved by July 1, 1983 are based on the degree of effluent reduction attainable through the application of the best available technology economically achievable. For the mining of minerals for the construction industry, this level of technology was based on the very best control and treatment technology employed by a specific point source within each of the industry's subcategories, or where it is readily transferable from one industry process to another. In Section IV, this segment of the mineral mining and processing industry was divided into nine major categories based on similarities of process. Several of those major categories have been further subcategorized and, for reasons explained in Section IV, each subcategory will be treated separately for the recommendation of effluent limitations guidelines and standards of performance.

The following factors were taken into consideration in determining the best available technology economically achievable:

(1) the age of equipment and facilities involved;
(2) the process employed;
(3) the engineering aspects of the application of various types of control techniques;
(4) process changes;
(5) cost of achieving the effluent reduction resulting from application of BATEA; and
(6) non-water quality environmental impact (including energy requirements).

In contrast to the best practicable technology currently available, best available technology economically achievable assesses the availability in all cases of in-process controls as well as control or additional treatment techniques employed at the end of a production process. In-process control options available which were considered in establishing these control and treatment technologies include the following:

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(1) alternative water uses
(2) water conservation
(3) waste stream segregation
(4) water reuse
(5) cascading water uses
(6) by-product recovery
(7) reuse of waste water constituents
(8) waste treatment
(9) good housekeeping
(10) preventive maintenance
(11) quality control (raw material, product, effluent)
(12) monitoring and alarm systems.

Those facility processes and control technologies which at the pilot facility, semi-works, or other level, have demonstrated both technological performances and economic viability at a level sufficient to reasonably justify investing in such facilities were also considered in assessing the best available technology economically achievable. Although economic factors are considered in this development, the costs for this level of control are intended to be for the top-of-the-line of current technology subject to limitations imposed by economic and engineering feasibility. However, this technology may necessitate some industrially sponsored development work prior to its application.

Based upon the information contained in Sections III through IX of this report, the following determinations were made on the degree of effluent reduction attainable with the application of the best available control technology economically achievable in the various subcategories of the mineral mining and processing industry.

Storm Water Runoff

Untreated overflow may be discharged from process waste water or mine drainage impoundments without limitation if the impoundments are designed, consturcted and operated to contain all process generated waste water or mine drainage and surface runoff into the impoundments resulting from a 25 year 24 hour precipitation event as established by the National Climatic Center, National Oceanic and Atmospheric Administration for the locality in which such impoundments are located. To preclude unfavorable water balance conditions resulting from precipitation and runoff in connection with tailing impoundments, diversion ditching should be constructed to prevent natural drainage or runoff from mingling with process waste water or mine drainage.

PROCESS WASTEWATER GUIDELINES AND LIMITATIONS, NO DISCHARGE GROUP

The following industry subcategories were required to achieve no discharge of process generated waste water pollutants to navigable waters based on best practicable control technology currently available:

- dimension stone
- crushed stone (dry)
- crushed stone (wet)
- crushed stone (flotation)
- construction sand and gravel (dry)
- consturction sand and gravel (wet)
- construction sand and gravel (dredging with land processing)
- industrial sand (dry)
- industrial sand (wet)
- industrial sand (acid and alkaline flotation)
- gypsum (dry)
- gypsum (heavy media separation)
- bituminous limestone
- oil impregnated diatomite
- gilsonite
- asbestos (dry)
- asbestos (wet)
- wollastonite
- perlite
- pumice
- vermiculite
- mica and sericite (dry)
- mica (wet, grinding)
- mica (wet beneficiation, either no clay or general purpose clay by-product)

The same limitations guidelines are recommended based on best available technology economically achievable.

INDUSTRIAL SAND (HF FLOTATION)

Based upon the information contained in Sections III through IX, a determination has been made that the degree of effluent reduction attainable through the application of the best available technology economically achievable is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best available technology economically achievable for the mining and processing of industrial sand by the HF flotation process is thickening, ponding to settle suspended solids, pH adjustment and total recycle of process water after segregation and total impoundment of the HF-containing segment of the process waste stream. To implement this technology at the one facility would require the installation of an impoundment pond and necessary piping.

This facility is located in an arid region and should be able to totally impound the HF-containing portion of its waste stream and recycle the remainder.

GYPSUM (WET SCRUBBING)

Based upon the information contained in Sections III through IX, a determination has been made that the degree of effluent reduction attainable through the application of the best available technology economically achievable is no discharge of process generated waste water pollutants.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best available technology economically achievable for the mining and processing of gypsum by the wet scrubbing process is the elimination of wet scrubbers by dry collection methods or total impoundment of scrubber water. To implement this technology at facilities not already using the recommended control techniques would require the installation of dry collection apparatus or impoundments for scrubber water. All the facilities presently using wet scrubbers have stated their intention to convert to dry collection methods.

MICA (WET BENEFICIATION PROCESS, CERAMIC GRADE CLAY BY-PRODUCT)

Based upon the information contained in Sections III through IX, a determination has been made that the degree of effluent reduction attainable through the application of the best available technology economically achievable is:

Effluent Characteristic	Effluent Limitation kg/kkg product (lbs/1000 lb) Monthly Average	Daily Maximum
TSS	1.25	2.5

The above limitations were based on the performance at one facility.

Based upon the data in Section V the following limits can be achieved for mine drainage and process contaminated runoff.

Effluent Characteristic	Effluent Limitation Daily Maximum
TSS	30 mg/l

Best available technology economically achievable for the mining and processing of mica by the wet beneficiation process where ceramic-grade clay is the by-product, is improved settling of suspended solids in ponds and lime treatment for pH adjustment prior to discharge. One of the two facilities in this subcategory is presently achieving the recommended level.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS AND PRETREATMENT STANDARDS

INTRODUCTION

This level of technology is to be achieved by new sources. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance." This technology is evaluated by adding to the consideration underlying the identification of best available technology economically achievable, a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques. Thus, in addition to considering the best in-facility and end-of-process control technology, new source performance standards are how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods of other alternatives were considered. However, the end result of the analysis identifies effluent standards which reflect levels of control achievable through the use of improved production processes (as well as control technology), rather than prescribing a particular type of process or technology which must be employed.

The following factors were considered with respect to production processes which were analyzed in assessing the best demonstrated control technology currently available for new sources:

a) the type of process employed and process changes;
b) operating methods;
c) batch as opposed to continuous operations;
d) use of alternative raw materials and mixes of raw materials;
e) use of dry rather than wet processes (including substitution of recoverable solvents from water); and
f) recovery of pollutants as by-products.

In addition to the effluent limitations covering discharges directly into waterways, the constituents of the effluent discharge from a facility within the industrial category which would interfere with, pass through, or otherwise be incompatible with a well designed and operated publicly owned activated sludge or trickling filter waste water treatment facility were identified. A determination was

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made of whether the introduction of such pollutants into the treatment facility should be completely prohibited.

GENERAL WATER GUIDELINES

The process water, cooling water, mine water pumpout, and blowdown guidelines for new sources are identical to those based on best available technology economically achievable.

PROCESS WATER GUIDELINES

Based upon the information contained in Sections III through X of this report, the following determinations were made on the degree of effluent reduction attainable with the application of new source standards for the various subcategories of the minerals for the construction industry segment of the mineral mining and processing industry.

Storm Water Runoff

Untreated overflow may be discharged from process waste water or mine drainage impoundments without limitation if the impoundments are designed, consturcted and operated to contain all process generated waste water or mine drainage and surface runoff into the impoundments resulting from a 25 year 24 hour precipitation event as established by the National Climatic Center, National Oceanic and Atmospheric Administration for the locality in which such impoundments are located. To preclude unfavorable water balance conditions resulting from precipitation and runoff in connection with tailing impoundments, diversion ditching should be constructed to prevent natural drainage or runoff from mingling with process waste water or mine drainage.

The following industry subcategories were required to achieve no discharge of process generated waste water pollutants to navigable waters based on best practicable control technology currently available:

- dimension stone
- crushed stone (dry)
- crushed stone (wet)
- crushed stone (flotation)
- construction sand and gravel (dry)
- construction sand and gravel (wet)
- construction sand and gravel (land processing)
- industrial sand (dry)
- industrial sand (wet)
- industrial sand (acid and alkaline flotation)
- gypsum (dry)
- gypsum (heavy media separation)
- bituminous limestone

oil impregnated diatomite
gilsonite
asbestos (dry)
asbestos (wet)
wollastonite
perlite
pumice
vermiculite
mica and sericite (dry)
mica (wet, grinding)
mica (wet beneficiation, either no clay or
  general purpose clay by-product)

The same limitations guidelines are recommended based on best available technology economically achievable.

The following industry subcategories were required to achieve no discharge of process generated waste water pollutants to navigable waters based on best available technology economically achievable:

industrial sand (HF flotation process)
gypsum (wet scrubbing)

The same limitations are recommended as new source performance standards.

The following industry subcategories are required to achieve specific effluent limitations as given in the following paragraphs.

MICA (WET BENEFICIATION, CERAMIC GRADE CLAY BY-PRODUCT)

Same as best available technology economically achievable.

PRETREATMENT STANDARDS

Recommended pretreatment guidelines for discharge of facility waste water into public treatment works conform in general with EPA Pretreatment Standards for Municipal Sewer Works as published in the July 19, 1973 Federal Register and "Title 40 - Protection of the Environment, Chapter 1 - Environmental Protection Agency, Subchapter D - Water Programs - Part 128 - Pretreatment Standards" a subsequent EPA publication. The following definitions conform to these publications:

a. Compatible Pollutant

The term "compatible pollutant" means biochemical oxygen demand, suspended solids, pH and fecal coliform bacteria, plus additional pollutants identified in the NPDES permit, if the publicly-owned treatment works was designed to treat such pollutants, and, in fact, does remove such pollutants to a substantial degree. Examples of such additional pollutants may include:

- chemical oxygen demand
- total organic carbon
- phosphorus and phosphorus compounds
- nitrogen and nitrogen compounds
- fats, oils, and greases of animal or vegetable origin except as defined below in 4.1 Prohibited Wastes.

b. Incompatible Pollutant

The term "incompatible pollutant" means any pollutant which is not a compatible pollutant as defined above.

c. Joint Treatment Works

Publicly owned treatment works for both non-industrial and industrial waste water.

d. Major Contributing Industry

A major contributing industry is an industrial user of the publicly owned treatment works that: has a flow of 50,000 gallons or more per average work day; has a flow greater than five percent of the flow carried by the municipal system receiving the waste; has in its waste, a toxic pollutant in toxic amounts as defined in standards issued under Section 307(a) of the Act; or is found by the permit issuance authority, in connection with the issuance of an NPDES permit to the publicly owned treatment works receiving the waste, to have significant impact, either singly or in combination with other contributing industries, on that treatment works or upon the quality of effluent from that treatment works.

e. Pretreatment

Treatment of waste waters from sources before introduction into the joint treatment works.

Prohibited Wastes

No waste introduced into a publicly owned treatment works shall interfere with the operation or performance of the works. Specifically, the following wastes shall not be introduced into the publicly owned treatment works:

a. Wastes which create a fire or explosion hazard in the publicly owned treatment works;

b. Wastes which will cause corrosive structural damage to treatment works, but in no case wastes with a pH lower than 5.0, unless the works are designed to accommodate such wastes;

c. Solid or viscous wastes in amounts which would cause obstruction to the flow in sewers, or other interference with the proper operation of the publicly owned treatment works, and

d. Wastes at a flow rate and/or pollutant discharge rate which is excessive over relatively short time periods so that there is a treatment process upset and subsequent loss of treatment efficiency.

Pretreatment for Incompatible Pollutants

In addition to the above, the pretreatment standard for incompatible pollutants introduced into a publicly owned treatment works by a major contributing industry shall be best practicable control technology currently available.

Recommended Pretreatment Guidelines

In accordance with the preceding Pretreatment Standards for Municipal Sewer Works, the following are recommended for Pretreatment Guidelines for the waste water effluents:

a. No pretreatment required for removal of compatible pollutants - biochemical oxygen demand, suspended solids (unless hazardous), pH, and fecal coliform bacteria;

b. Suspended solids containing hazardous pollutants such as heavy metals, cyanides and chromates should conform to be restricted to those quantities recommended in Section IX Guidelines for Best Practical Control Technology Currently Available for existing sources and new sources performance standards for new sources;

c. Pollutants such as chemical oxygen demand, total organic carbon, phosphorus and phosphorus compounds, nitrogen and nitrogen compounds, and fats, oils, and greases, need not be removed provided the publicly owned treatment works was designed to treat such pollutants and will accept them. Otherwise levels should be at best practicable control technology currently available recommendations for existing sources and at new source performance standards recommendations for new sources;

d. Limitation on dissolved solids is not recommended except in cases of water quality violations.

SECTION XII

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Louisiana Water Pollution Control Board
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National Crushed Stone Association
National Industrial Sand Association
National Limestone Institute
National Sand and Gravel Association

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SECTION XIII

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SECTION XIV

GLOSSARY

Aeration - the introduction of air into the pulp in a flotation cell in order to form air bubbles.

Aquifer - an underground stratum that yields water.

Baghouse - chamber in which exit gases are filtered through membranes (bags) which arrest solids.

Bench - a ledge, which, in open pit mines and quarries, forms a single level of operation above which mineral or waste materials are excavated from a contiguous bank or bench face.

Berm - a horizontal shelf built for the purpose of strengthening and increasing the stability of a slope or to catch or arrest slope slough material; berm is sometimes used as a synonym for bench.

Cell, cleaner - secondary cells for the retreatment of the concentrate from primary cells.

Cell, rougher - flotation cells in which the bulk of the gangue is removed from the ore.

Clarifier - a centrifuge, settling tank, or other device, for separating suspended solid matter from a liquid.

Classifier, air - an appliance for approximately sizing crushed minerals or ores employing currents of air.

Classifier, rake - a mechanical classifier utilizing reciprocal rakes on an inclined plane to separate coarse from fine material contained in a water pulp.

Classifier, spiral - a classifier for separating fine-size solids from coarser solids in a wet pulp consisting of an interrupted-flight screw conveyor, operating in an inclined trough.

Collector - a heteropolar compound chosen for its ability to adsorb selectively in froth flotation and render the adsorbing surface relatively hydrophobic.

Conditioner - an apparatus in which the surfaces of the mineral species present in a pulp are treated with appropriate chemicals to influence their reaction during aeration.

Crusher, cone - a machine for reducing the size of materials by means of a truncated cone revolving on its vertical axis within an outer chamber, the anular space between the outer chamber and cone being tapered.

Crusher, gyratory - a primary crusher consisting of a vertical spindle, the foot of which is mounted in an eccentric bearing within a conical shell. The top carries a conical crushing head revolving eccentrically in a conical maw.

Crusher, jaw - a primary crusher designed to reduce the size of materials by impact or crushing between a fixed plate and an oscillating plate or between two oscillating plates, forming a tapered jaw.

Crusher, roll - a reduction crusher consisting of a heavy frame on which two rolls are mounted; the rolls are driven so that they rotate toward one another. Rock is fed in from above and nipped between the moving rolls, crushed, and discharged below.

Depressant - a chemical which causes substances to sink through a froth, in froth flotation.

Dispersant - a substance (as a polyphosphate) for promoting the formation and stabilization of a dispersion of one substance in another.

Blunge - to mix thoroughly.

Burden - valueless material overlying the ore.

Dragline - a type of excavating equipment which employs a rope-hung bucket to dig up and collect the material.

Dredge, bucket - a two-pontooned dredge from which are suspended buckets which excavate material at the bottom of the pond and deposit it in concentrating devices on the dredge decks.

Dredge, suction - a centrifugal pump mounted on a barge.

Drill, churn - a drilling rig utilizing a blunt-edged chisel bit suspended from a cable for putting down vertical holes in exploration and quarry blasting.

Drill, diamond - a drilling machine with a rotating, hollow, diamond-studded bit that cuts a circular channel around a core which when recovered provides a columnar sample of the rock penetrated.

Drill, rotary - various types of drill machines that rotate a rigid, tubular string of rods to which is attached a bit for cutting rock to produce boreholes.

Dryer, flash - an appliance in which the moist material is fed into a column of upward-flowing hot gases with moisture removal being virtually instantaneous.

Dryer, fluidized bed - a cool dryer which depends on a mass of particles being fluidized by passing a stream of hot air through it. As a result of the fluidization, intense turbulence is created in the mass including a rapid drying action.

Dryer, rotary - a dryer in the shape of an inclined rotating tube used to dry loose material as it rolls through.

Electrostatic separator - a vessel fitted with positively and negatively charged conductors used for extracting dust from flue gas or for separating mineral dust from gangues.

Filter, pressure - a machine utilizing pressure to increase the removal rate of solids from tailings.

Filter, vacuum - a filter in which the air beneath the filtering material is exhausted to hasten the process.

Flocculant - an agent that induces or promotes gathering of suspended particles into aggregations.

Flotation - the method of mineral separation in which a froth created in water by a variety of reagents floats some finely crushed minerals, whereas other minerals sink.

Frother - substances used in flotation to make air bubbles sufficiently permanent, principally by reducing surface tension.

Grizzly - a device for the coarse screening or scalping of bulk materials.

HMS - Heavy Media Separation

Hydraulic Mining - mining by washing sand and dirt away with water which leaves the desired mineral.

Hydrocyclone - a cyclone separator in which a spray of water is used.

Hydroclassifier - a machine which uses an upward current of water to remove fine particles from coarser material.

Humphrey spiral - a concentrating device which exploits differential densities of mixed sands by a combination of sluicing and centrifugal action. The ore pulp gravitates down through a stationary spiral trough with five turns. Heavy particles stay on the inside and the lightest ones climb to the outside.

Jumbo - a drill carriage on which several drills are mounted.

JTU - Jackson Turbidity Unit

Kiln, rotary - a kiln in the form of a long cylinder, usually inclined, and slowly rotated about its axis; the kiln is fired by a burner set axially at its lower end.

Kiln, tunnel - a long tunnel-shaped furnace through which ware is generally moved on cars, passing progressively through zones in which the temperature is maintained for preheating, firing and cooling.

Launder - a chute or trough for conveying powdered ore, or for carrying water to or from the crushing apparatus.

Log washer - a slightly slanting trough in which revolves a thick shaft or log, carring blades obliquely set to the axis. Ore is fed in at the lower end, water at the upper. The blades slowly convey the lumps of ore upward against the current, while any adhering clay is gradually disintegrated and floated out the lower end.

Magnetic separator - a device used to separate magnetic from less magnetic or nonmagnetic materials.

Mill, ball - a rotating horizontal cylinder in which non-metallic materials are ground using various types of grinding media such as quartz pebbles, porcelain balls, etc.

Mill, buhr - a stone disk mill, with an upper horizontal disk rotating above a fixed lower one.

Mill, chaser - a cylindrical steel tank lined with wooden rollers revolving 15-30 times a minute.

Mill, hammer - an impact process facility consisting of a rotor, fitted with movable hammers, that is revolved rapidly in a vertical plane within a closely fitting steel casing.

Mill, pebble - horizontally mounted cylindrical mill, charged with flints or selected lumps of ore or rock.

Mill, rod - a process facility for fine grinding, somewhat similar to a ball mill, but employing long steel rods instead of balls to effect the grinding.

Mill, roller - a fine grinding process facility having vertical rollers running in a circular enclosure with a stone or iron base.

Neutralization - making neutral or inert, as by the addition of an alkali or an acid solution.

Outcrop - the part of a rock formation that appears at the surface of the ground or deposits that are so near to the surface as to be found easily by digging.

Overburden - material of any nature, consolidated or unconsolidated, that overlies a deposit of useful materials, ores, etc.

Permeability - capacity for transmitting a fluid.

Raise - an inclined opening driven upward from a level to connect with the level above or to explore the ground for a limited distance above one level.

Reserve - known ore bodies that may be worked at some future time.

Ripper - a tractor accessory used to loosen compacted soils and soft rocks for scraper loading.

Room and Pillar - a system of mining in which the distinguishing feature is the winning of 50 percent or more of the ore in the first working. The ore is mined in rooms separated by narrow ribs (pillars); the ore in the pillars is won by subsequent working in which the roof is caved in successive blocks.

Scraper - a tractor-driven surface vehicle the bottom of which is fitted with a cutting blade which when lowered is dragged through the soil.

Scrubber, dust - special apparatus used to remove dust from air by washing.

Scrubber, ore - device in which coarse and sticky ore is washed free of adherent material, or mildly disintegrated.

Shuttle-car - a vehicle which transports raw materials from loading machines in trackless areas of a mine to the main transportation system.

Sink-float - processes that separate particles of different sizes or composition on the basis of specific gravity.

Skip - a guided steel hoppit used in vertical or inclined shafts for hoisting mineral.

Slimes - extremely fine particles derived from ore, associated rock, clay or altered rock.

Sluice - to cause water to flow at high velocities for wastage, for purposes of excavation, ejecting debris, etc.

Slurry - pulp not thick enough to consolidate as a sludge but sufficiently dewatered to flow viscously.

Stacker - a conveyor adapted to piling or stacking bulk materials or objects.

Stope - an excavation from which ore has been excavated in a series of steps.

Stripping ratio - the unit amount of spoil that must be removed to gain access to a similar unit amount of ore or mineral material.

Sump - any excavation in a mine for the collection of water for pumping.

Table, air - a vibrating, porous table using air currents to effect gravity concentration of sands.

Table, wet - a concentration process whereby a separation of minerals is effected by flowing a pulp across a riffled plane surface inclined slightly from the horizontal, differentially shaken in the direction of the long axis and washed with an even flow of water at right angles to the direction of motion.

Thickener - an apparatus for reducing the proportion of water in a pulp.

TSS - total suspended solids.

Waste - the barren rock in a mine or the part of the ore deposit that is too low in grade to be of economic value at the time.

Weir - an obstruction placed across a stream for the purpose of channeling the water through a notch or an opening in the weir itself.

Wire saw - a saw consisting of one- and three-strand wire cables, running over pulleys as a belt. When fed by a slurry of sand and water and held against rock by tension, it cuts a narrow channel by abrasion.

TABLE 24

METRIC UNITS

CONVERSION TABLE

Multiply (English Units)		by	To obtain (Metric units)	
ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/ pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	F°	0.555 (°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
tons (short)	t	0.907	kkg	metric tons (1000 kilograms)
yard	y	0.9144	m	meters

*Actual conversion, not a multiplier

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